Network Systems Science & Advanced Computing

Biocomplexity Institute & Initiative

University of Virginia

Estimation of COVID-19 Impact in Virginia

October 21st, 2020

(data current to October 20th)

Biocomplexity Institute Technical report: TR 2020-129

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About Us

- Biocomplexity Institute at the University of Virginia
  - Using big data and simulations to understand massively interactive systems and solve societal problems
- Over 20 years of crafting and analyzing infectious disease models
  - Pandemic response for Influenza, Ebola, Zika, and others

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Overview

- **Goal**: Understand impact of COVID-19 mitigations in Virginia
- **Approach:**
  - Calibrate explanatory mechanistic model to observed cases
  - Project infections through December
  - Consider a range of possible mitigation effects in "what-if" scenarios
- **Outcomes:**
  - Ill, Confirmed, Hospitalized, ICU, Ventilated, Death
  - Geographic spread over time, case counts, healthcare burdens

Key Takeaways

Projecting future cases precisely is impossible and unnecessary.
Even without perfect projections, we can confidently draw conclusions:

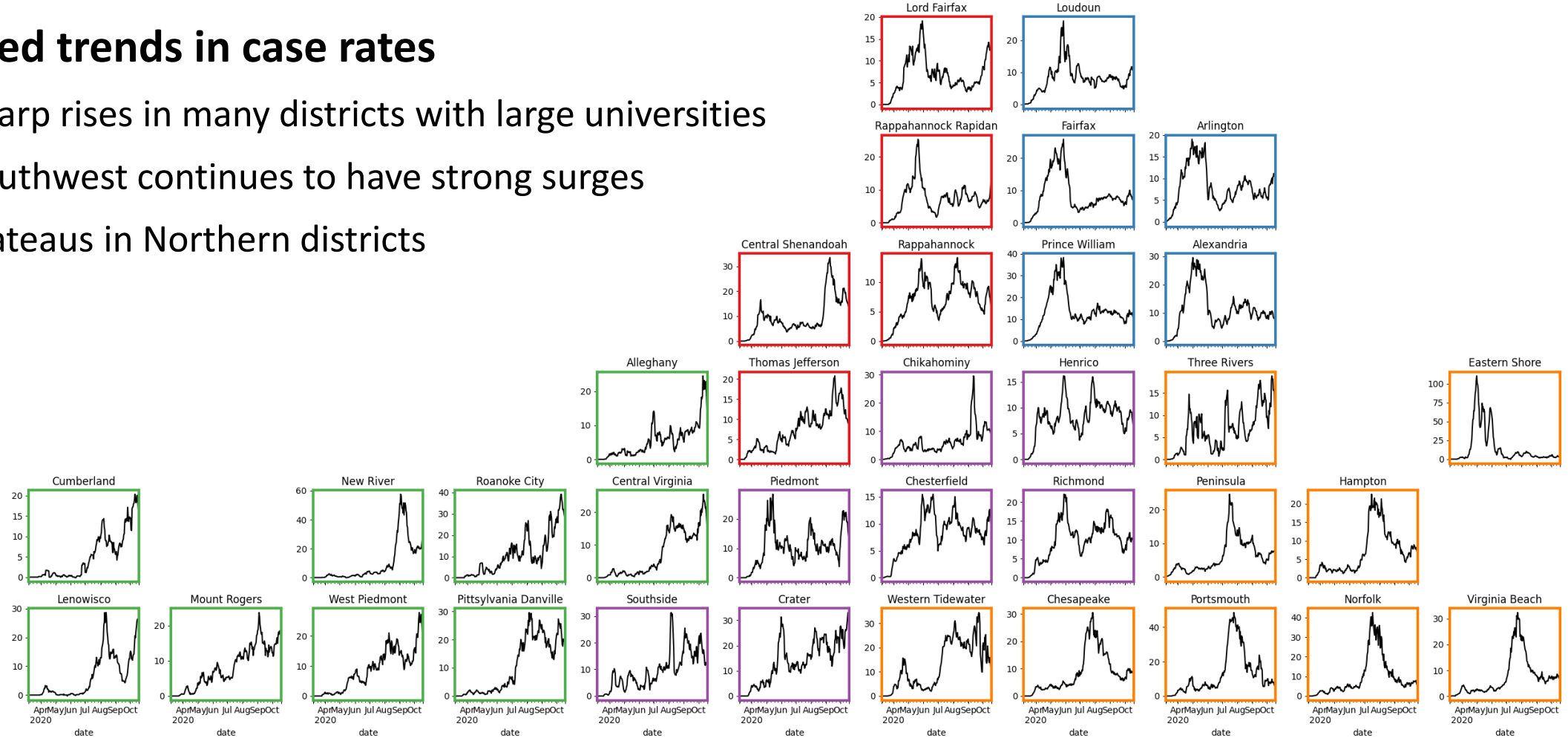
- **Virginia is steady while many states surge, though growth outpaces declines in the districts.**
- VA weekly incidence (11.6/100K) is steady and below the growing national average (23/100K).
- Projections are mostly up, but many districts continue to decline.
- Recent updates:
  - Planning Scenarios adjusted, as Adaptive Fitting tracks recent surge, to represent population's ability to exert further control on transmission following Thanksgiving holidays, Nov 26th.
  - Design used to capture uncertainty adjusted to better capture higher case ascertainment.
- The situation is changing rapidly. Models will be updated regularly.

Situation Assessment

Case Rate (per 100k) by VDH District

Mixed trends in case rates

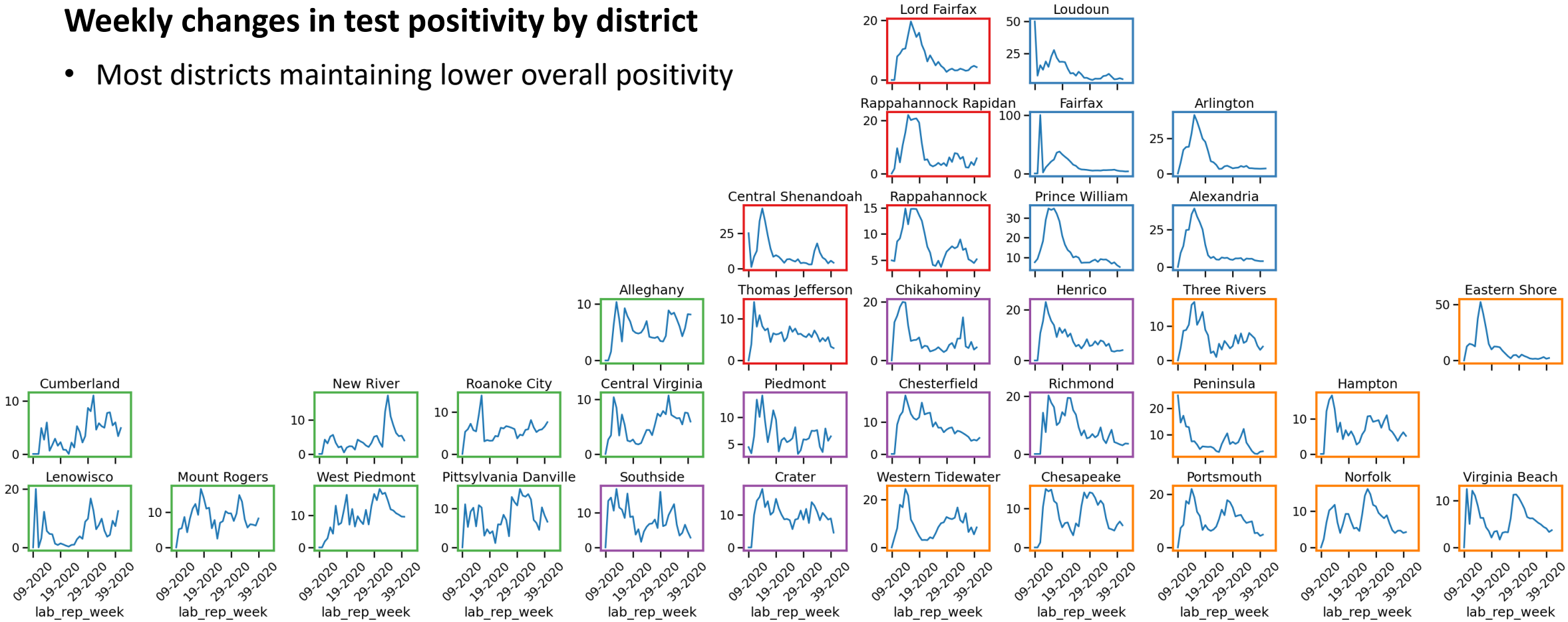
- Sharp rises in many districts with large universities
- Southwest continues to have strong surges
- Plateaus in Northern districts



Test Positivity by VDH District

Weekly changes in test positivity by district

- Most districts maintaining lower overall positivity



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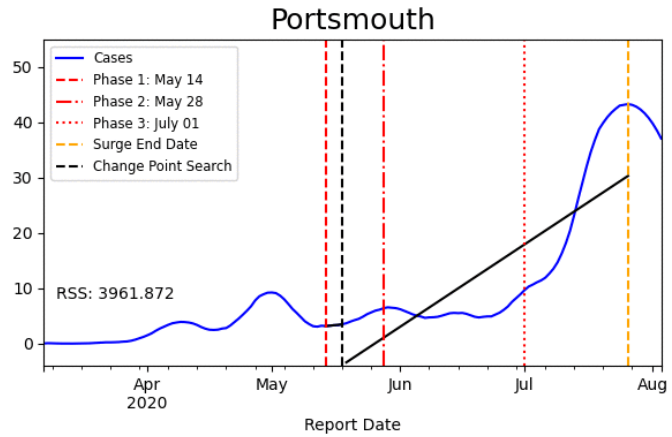
District Trajectories

Goal: Define epochs of a Health District's COVID-19 incidence to characterize the current trajectory

Method: Find recent peak and use hockey stick fit to find inflection point afterwards, then use this period's slope to define the trajectory

Hockey stick fit

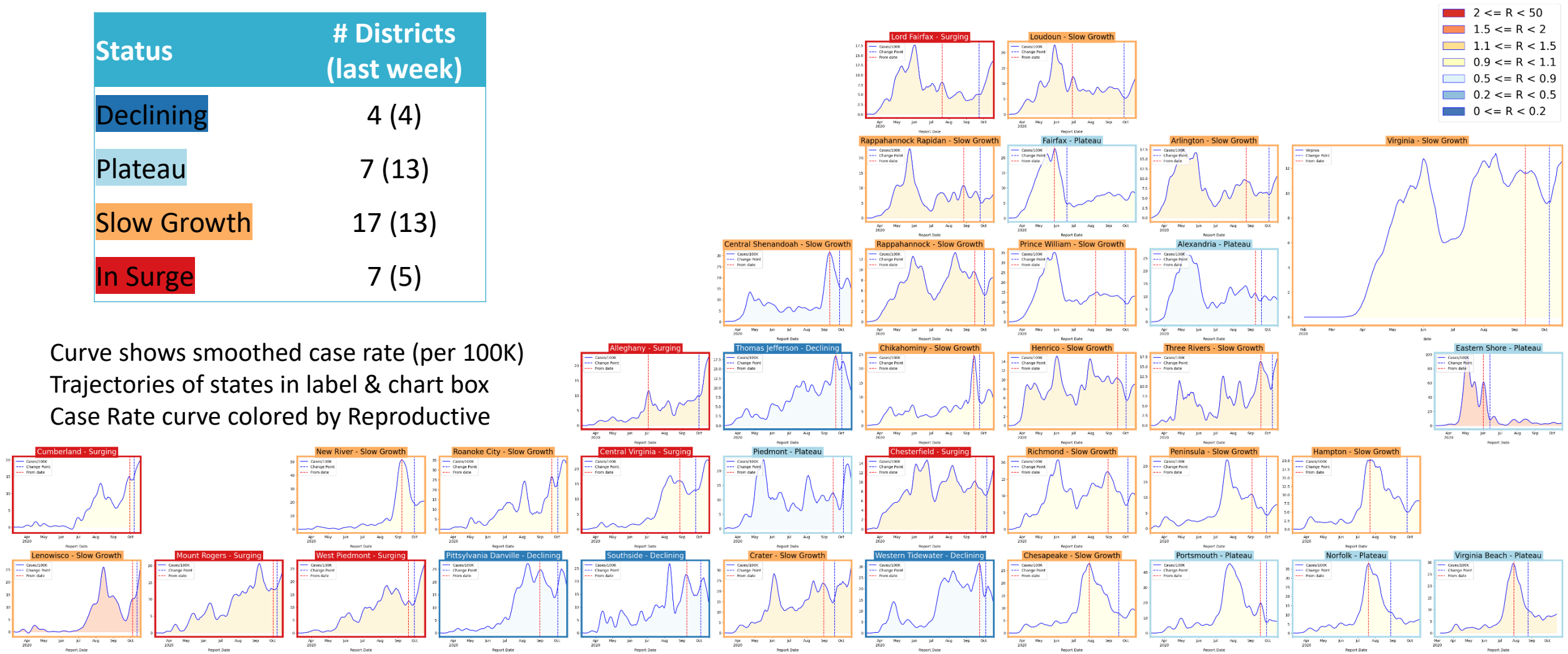


Trajectory	Description	Weekly Case Rate (per 100K) bounds	# Districts (last week)
Declining	Sustained decreases following a recent peak	below -0.9	4 (4)
Plateau	Steady level with minimal trend up or down	above -0.9 and below 0.5	7 (13)
Slow Growth	Sustained growth not rapid enough to be considered a Surge	above 0.5 and below 2.5	17 (13)
In Surge	Currently experiencing sustained rapid and significant growth	2.5 or greater	7 (5)

District Trajectories – Growth predominates

Status	# Districts (last week)
Declining	4 (4)
Plateau	7 (13)
Slow Growth	17 (13)
In Surge	7 (5)

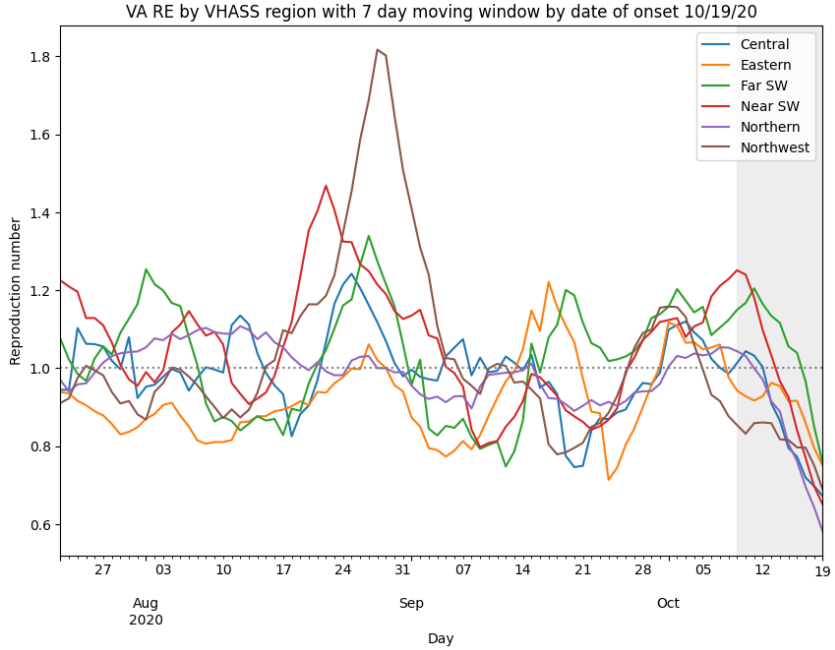
Curve shows smoothed case rate (per 100K)
Trajectories of states in label & chart box
Case Rate curve colored by Reproductive



Estimating Daily Reproductive Number

October 10th Estimates

Region	Current R_e	Diff Last Week
State-wide	1.037	0.006
Central	1.043	-0.024
Eastern	0.928	-0.088
Far SW	1.167	0.012
Near SW	1.240	0.209
Northern	1.031	0.070
Northwest	0.832	-0.260



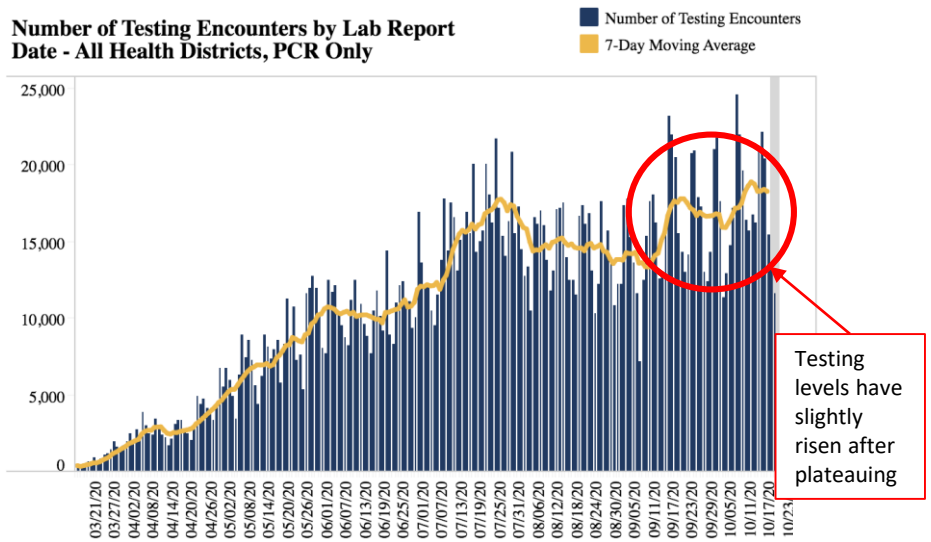
Methodology

- Wallinga-Teunis method (EpiEstim[1]) for cases by date of onset
- Serial interval: 6 days (2 day std dev)
- Recent estimates may be unstable due to backfill

1. Anne Cori, Neil M. Ferguson, Christophe Fraser, Simon Cauchemez. A New Framework and Software to Estimate Time-Varying Reproduction Numbers During Epidemics. American Journal of Epidemiology, Volume 178, Issue 9, 1 November 2013, Pages 1505–1512, https://doi.org/10.1093/aje/kwt133

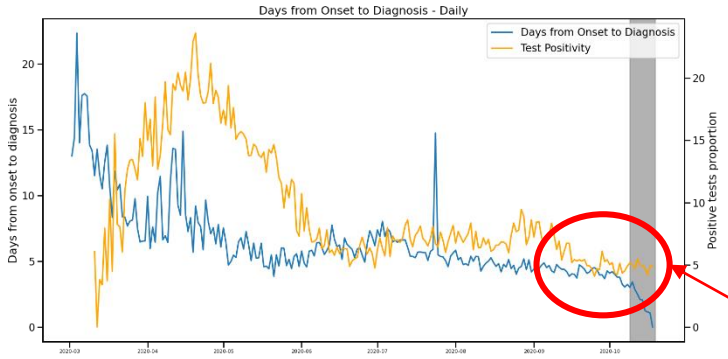
Changes in Case Detection

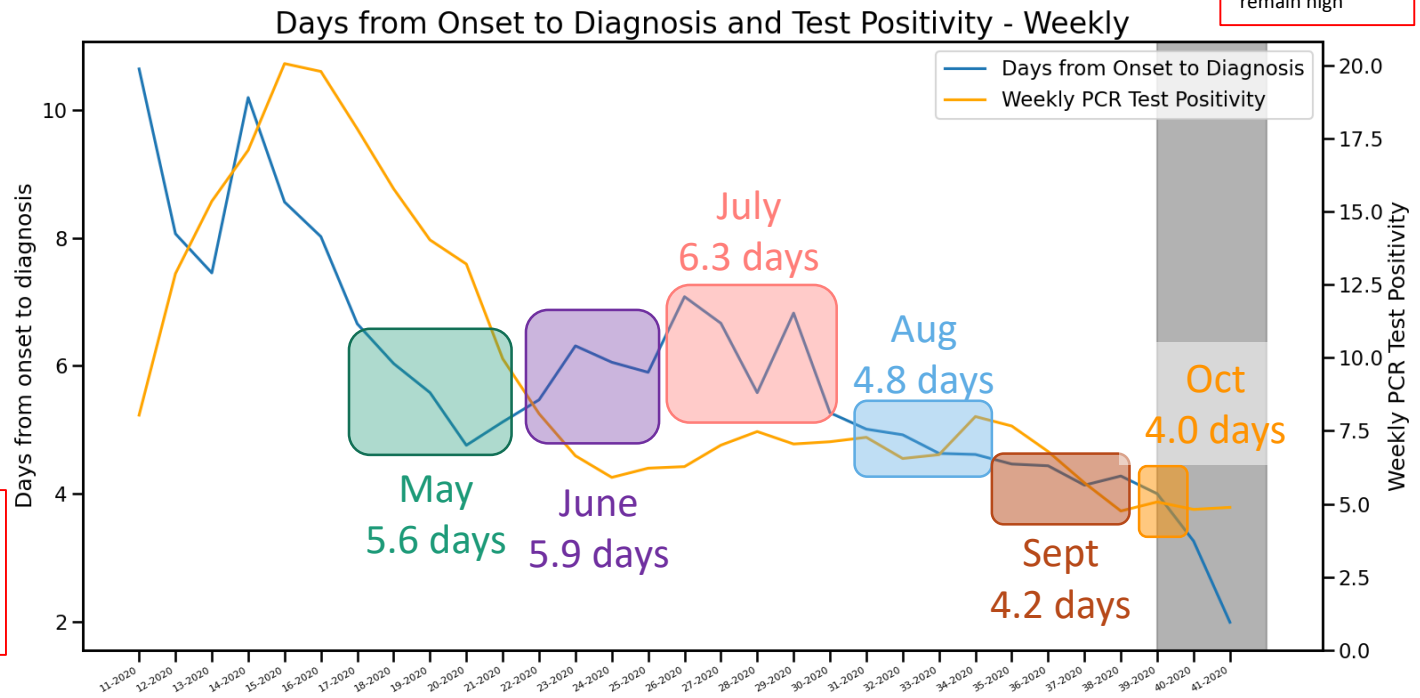
Timeframe (weeks)	Mean days	% difference from overall mean
April (13-16)	8.56	46%
May (17-21)	5.63	-4%
June (22-25)	5.93	1%
July (26-30)	6.28	7%
Aug (31-34)	4.79	-18%
Sept (35-38)	4.33	-26%
Oct (39)	4	-32%
Overall (13-37)	5.85	0%



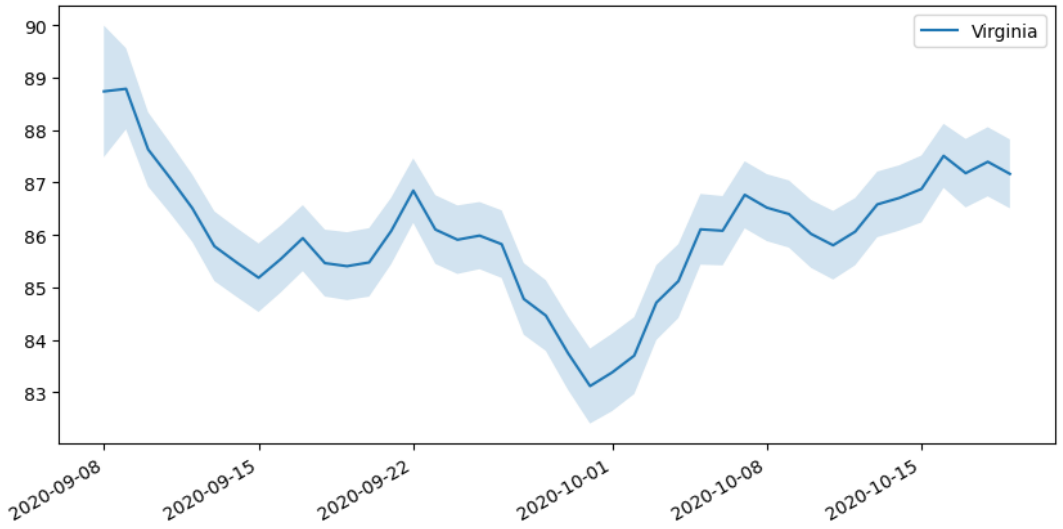
Accessed 9:30am October 21, 2020
https://www.vdh.virginia.gov/coronavirus/

Test positivity vs. Onset to Diagnosis





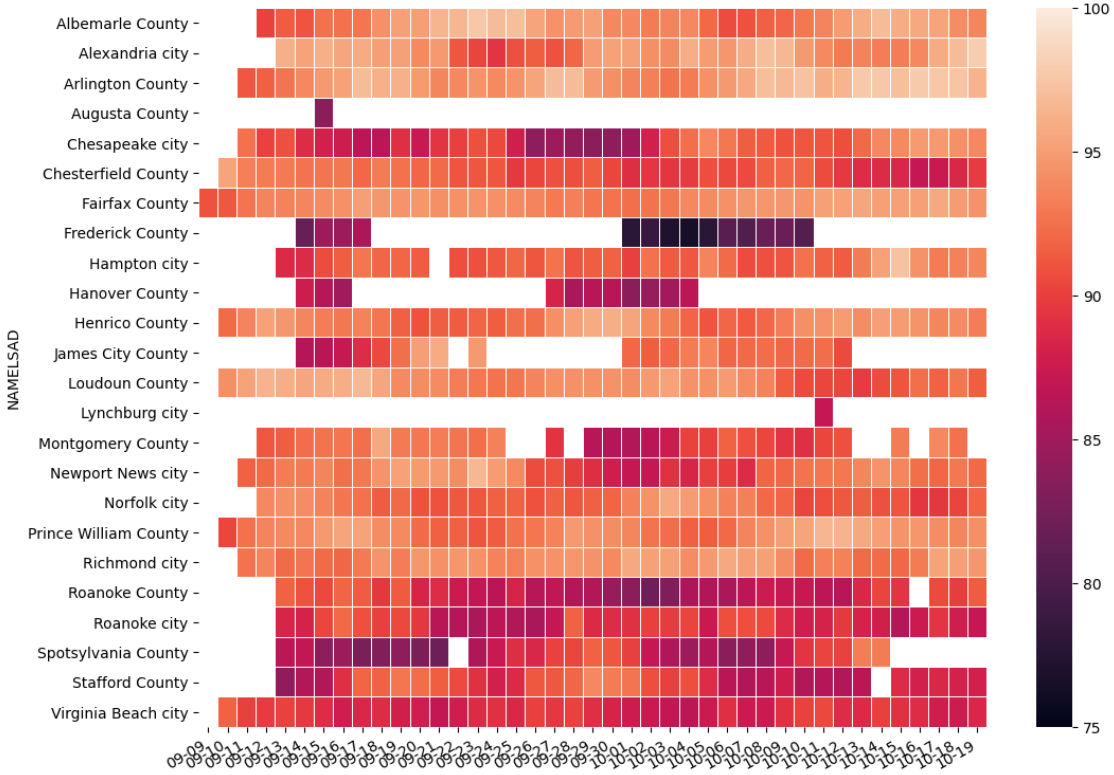
Mask usage in Virginia



State level mask usage as reported via Facebook surveys over the past month shows ranges from 83% to 89%

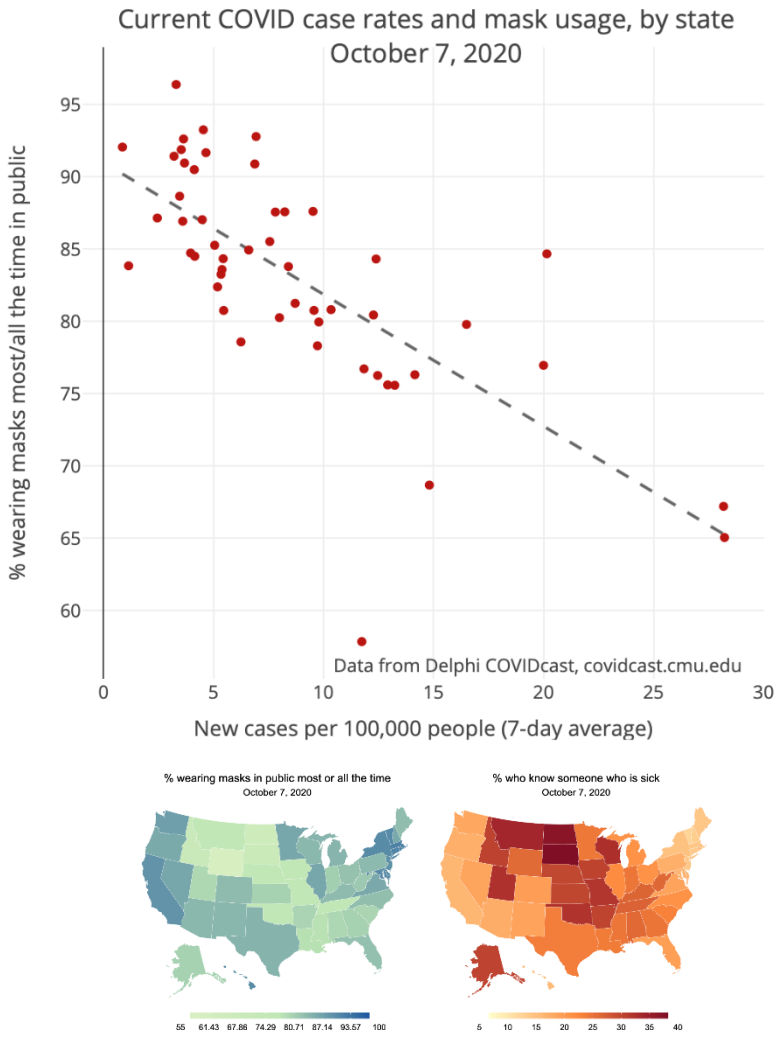
- Relatively stable over time
- Limited variance across the commonwealth
- ~3000 daily responses from VA.

Data Source: https://covidcast.cmu.edu



Some fluctuations over the last month in specific counties. Data quality may be affected by sample sizes.

Mask usage and Case Rates

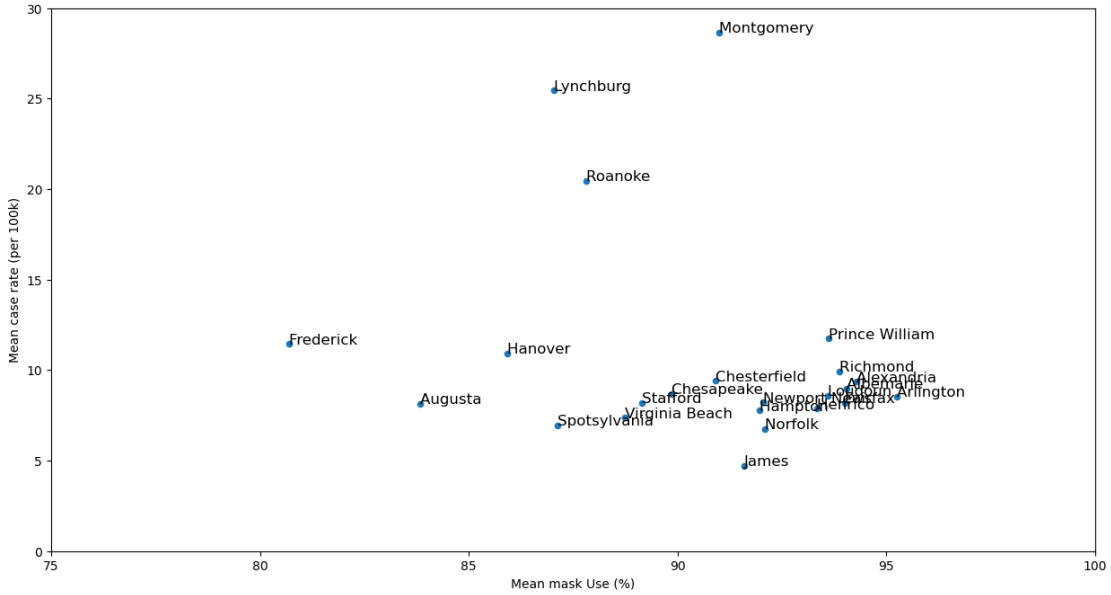


https://delphi.cmu.edu/blog/2020/10/12/new-and-improved-covid-symptom-survey-tracks-testing-and-mask-wearing/

Nationally strong correlation seen with mask wearing in a state and its recent case rates

Same correlation not found across VA counties

- University counties disrupt correlation
- VA counties vary less than the states in mask usage



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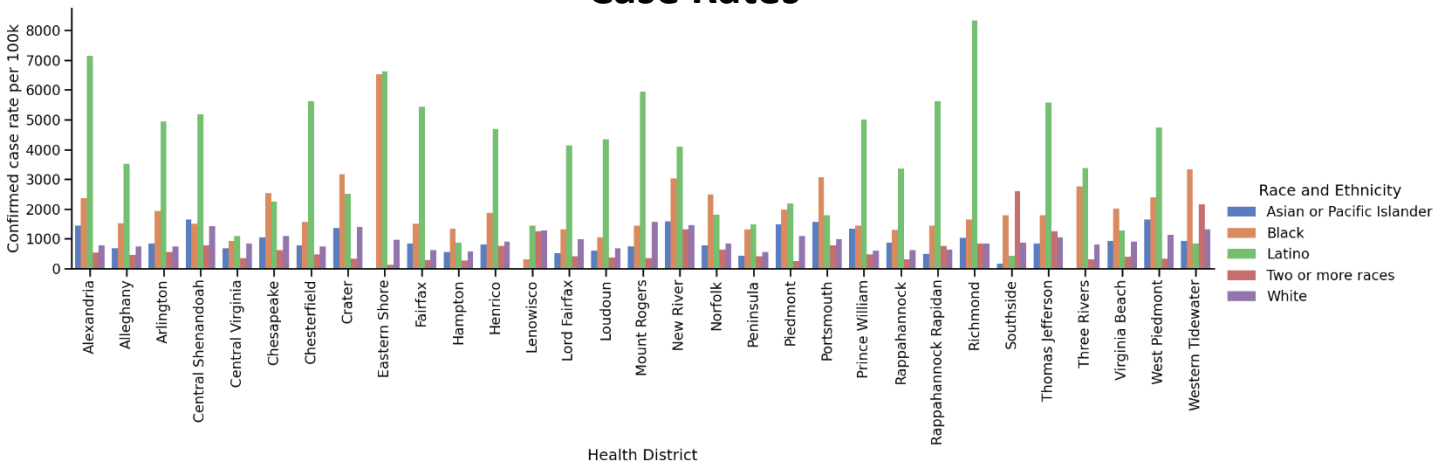
Race and Ethnicity cases per 100K

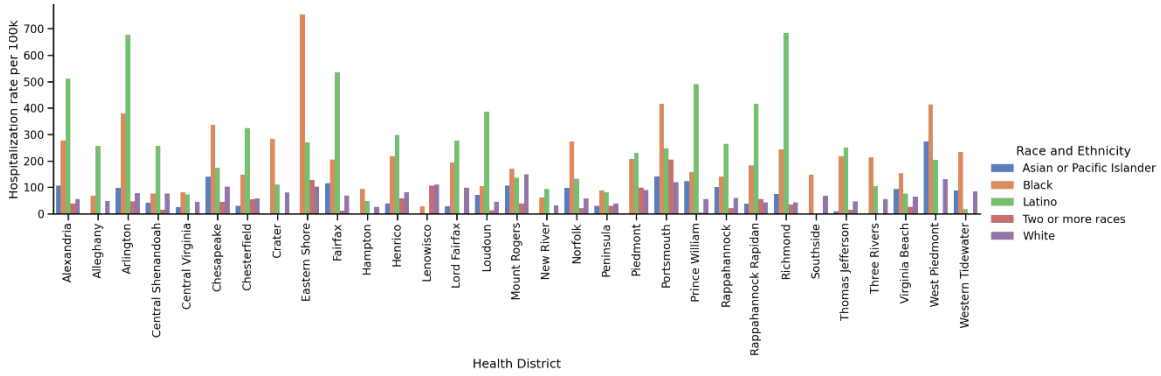
Rates per 100K of each Racial-Ethnic population by Health District

- Black and Latino populations have much higher case, hospitalization, and death rates
- More pronounced in some districts
- Based on 2019 census race-ethnicity data by county

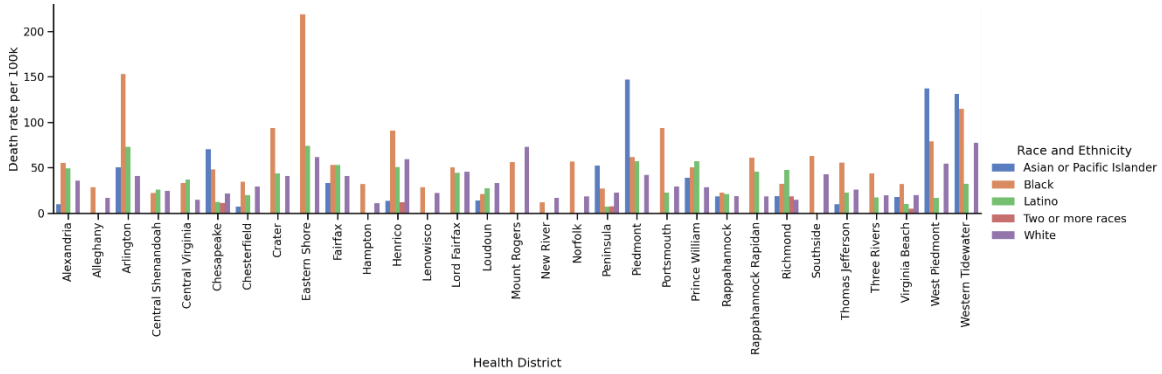
Case Rates



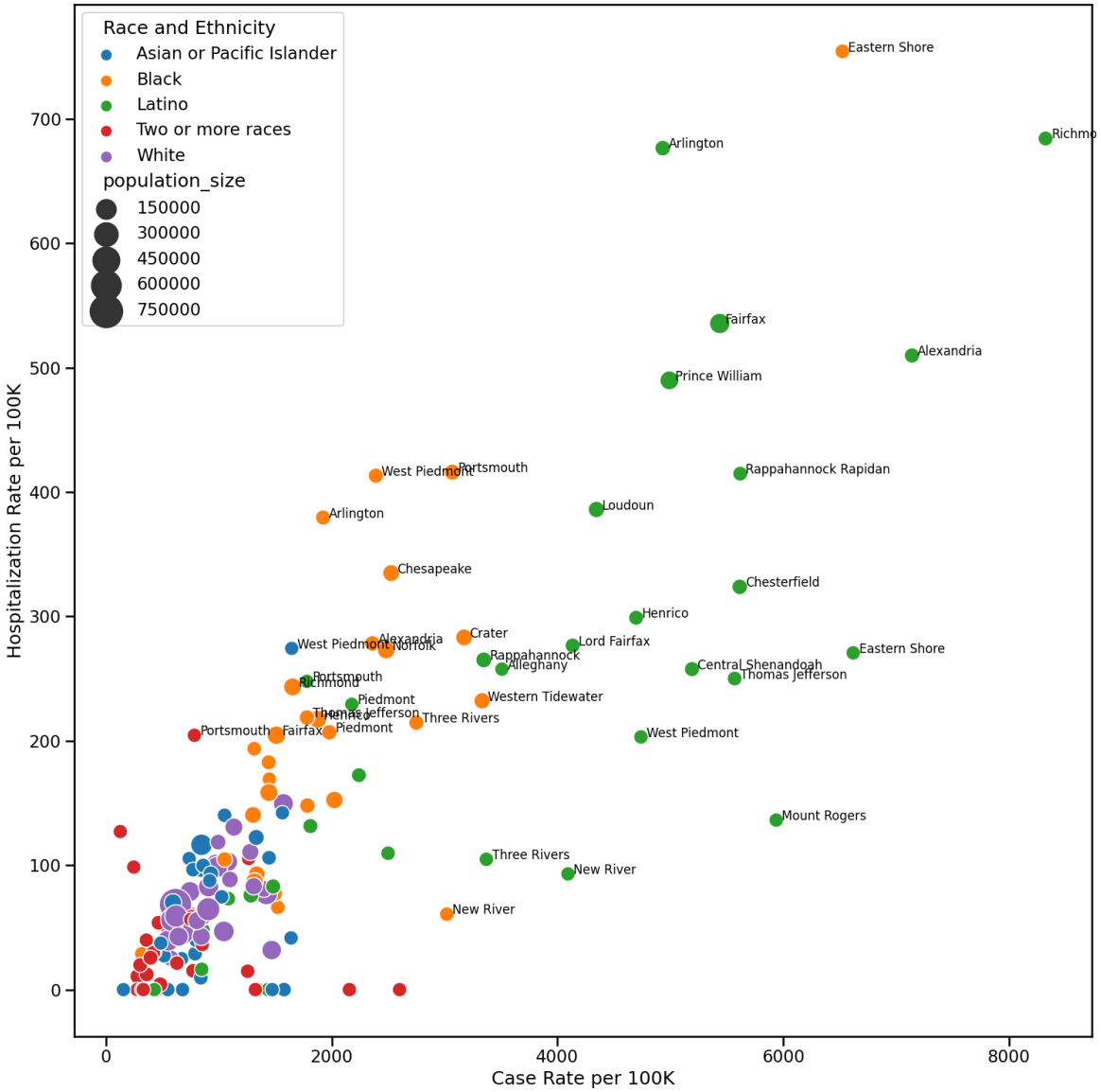
Hospitalization Rates



Death Rates



Race and Ethnicity cases per 100K



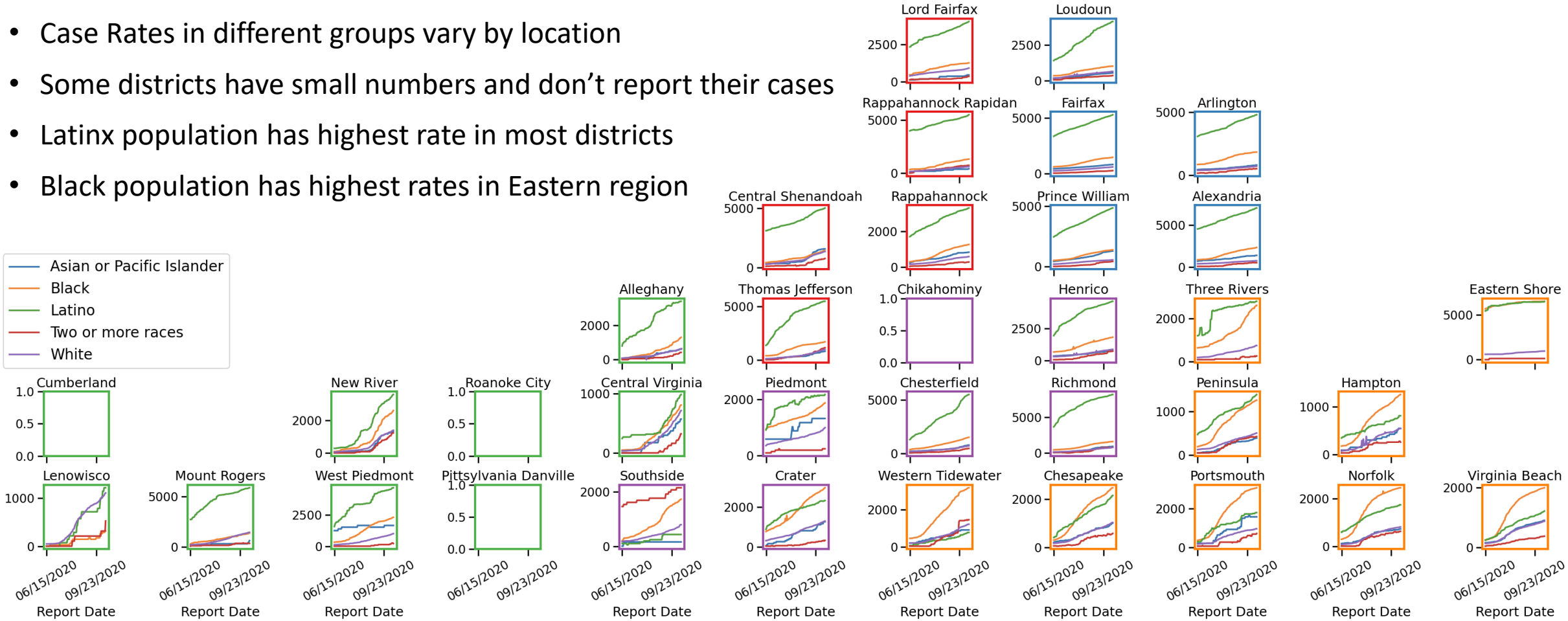
Rates per 100K of each Racial-Ethnic population by Health District

- Each Health District's Racial-Ethnic population is plotted by their Hospitalization and Case Rate
- Points are sized based on their overall population size
- Overlapping labels removed for clarity

Race and Ethnicity Attack Rates (per 100K)

Cumulative Race and Ethnicity Attack Rates (per 100k)

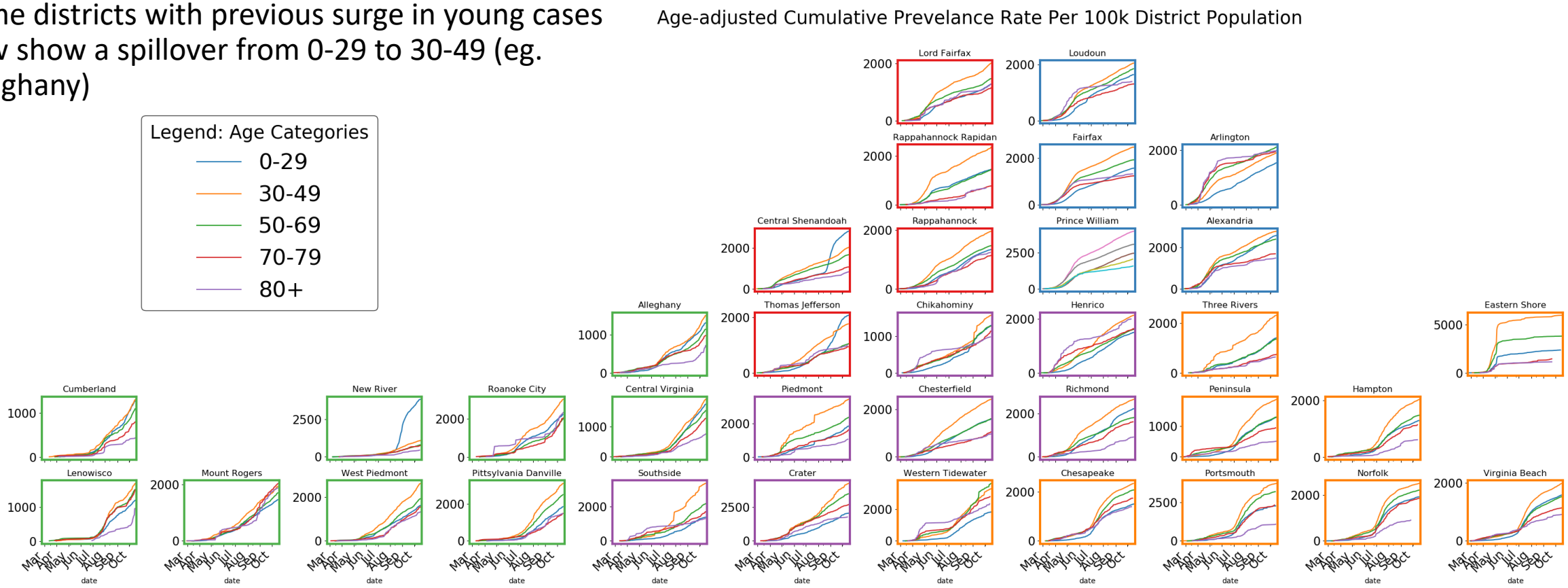
- Case Rates in different groups vary by location
- Some districts have small numbers and don't report their cases
- Latinx population has highest rate in most districts
- Black population has highest rates in Eastern region



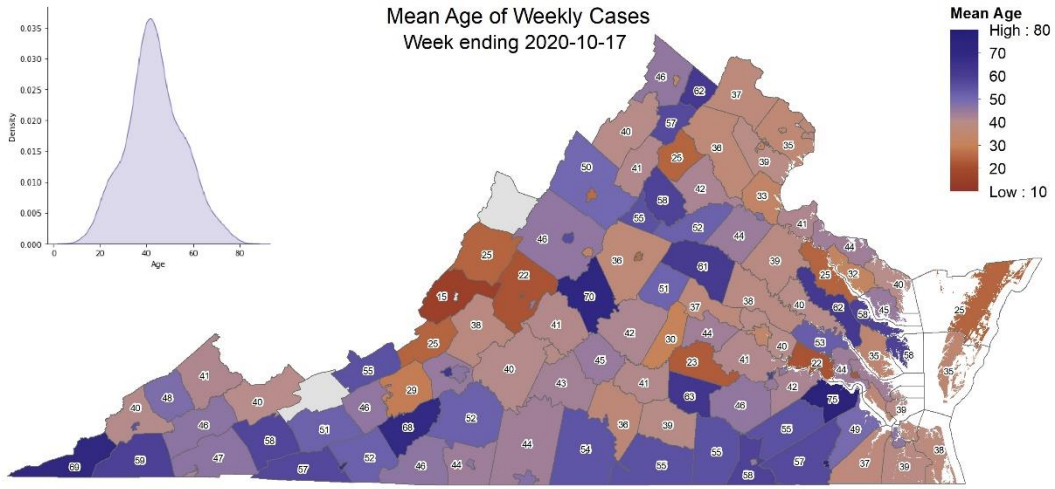
Age-Specific Attack Rates (per 100K)

Cumulative Age-specific Attack Rates (per 100k)

- Younger age groups outpace older in many districts
- Some districts with previous surge in young cases now show a spillover from 0-29 to 30-49 (eg. Alleghany)



Age-Specific Case Prevalence



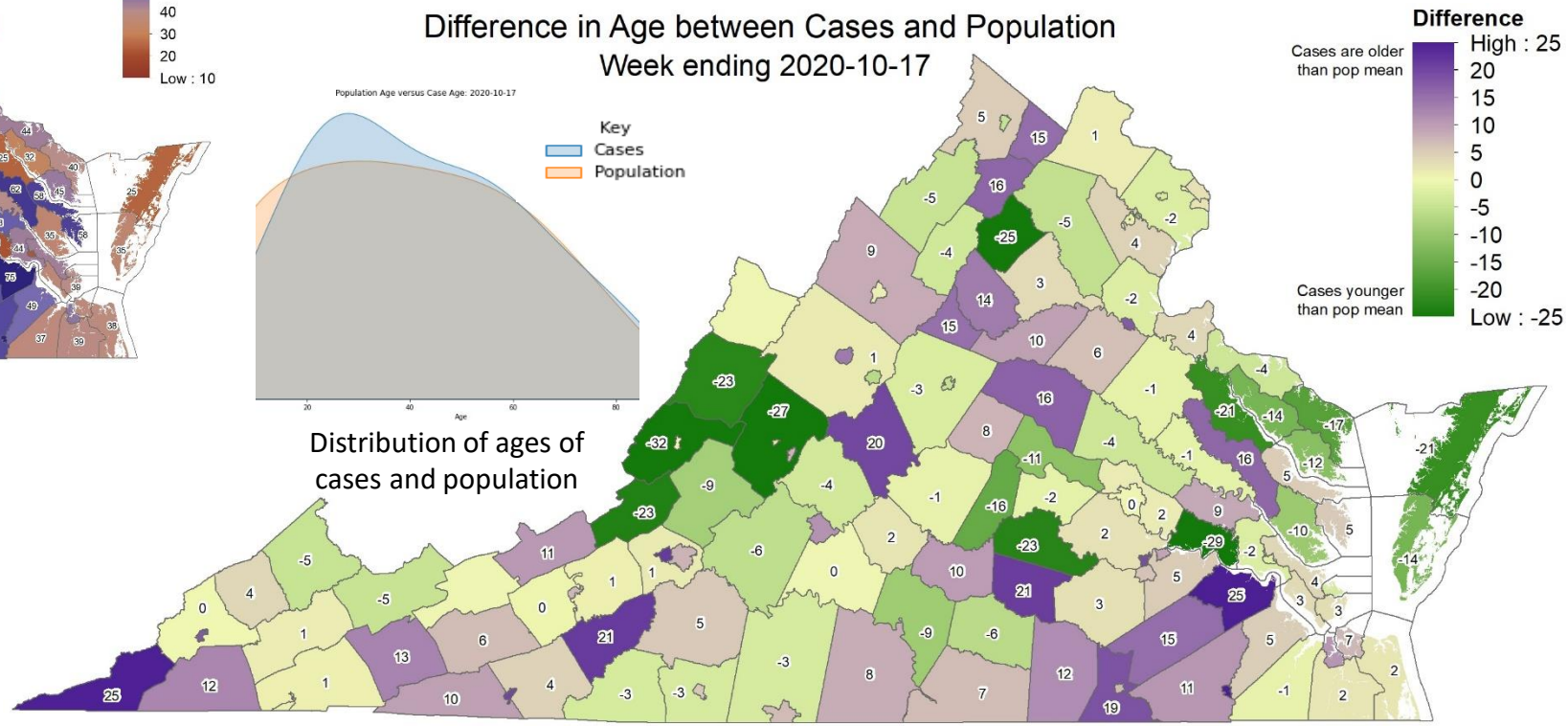
What is the average age of the cases by county?

Younger cases in Northern VA, Far SW, Tidewater, and around universities

How different is this from the Population?

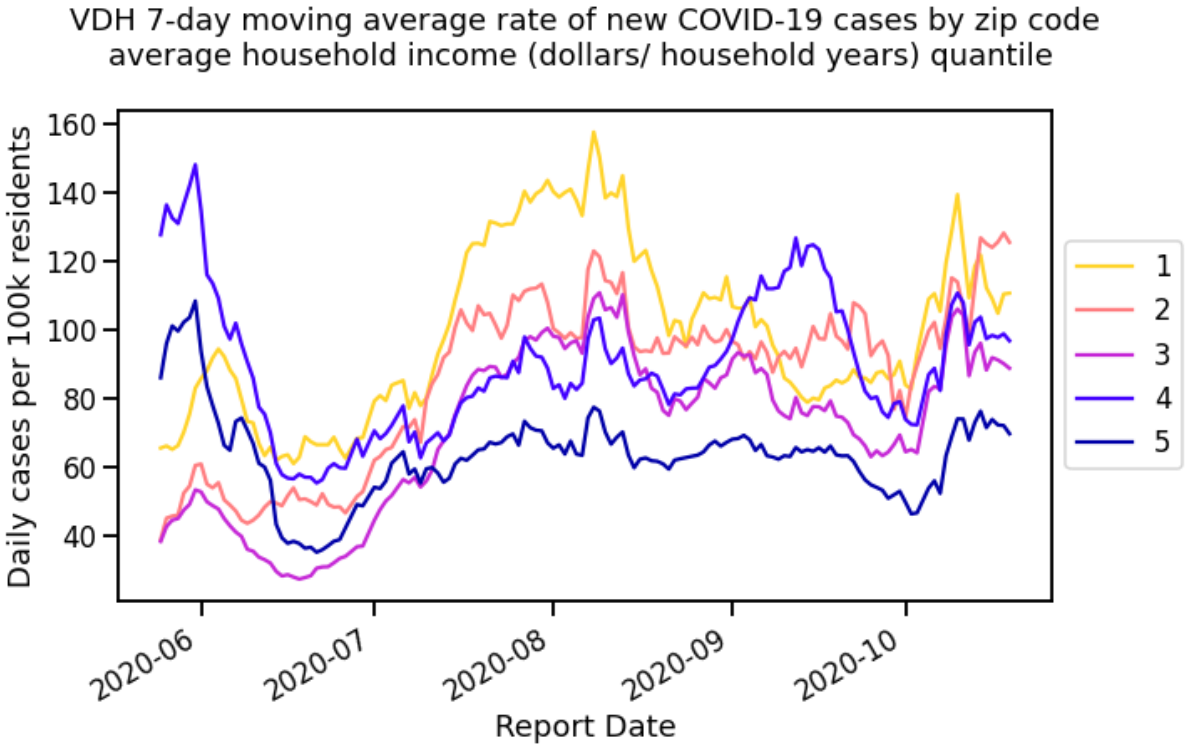
Difference in mean age of cases vs. population as a whole

Purple = Cases are older than pop; Green = Cases are younger than pop

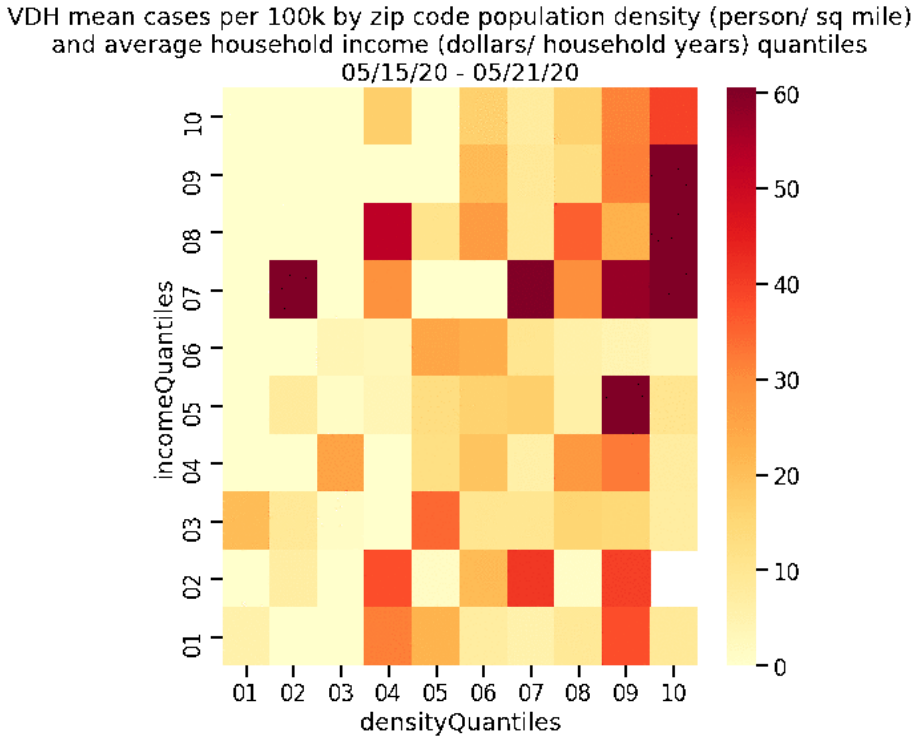


Distribution of ages of cases and population

Impact across Density and Income



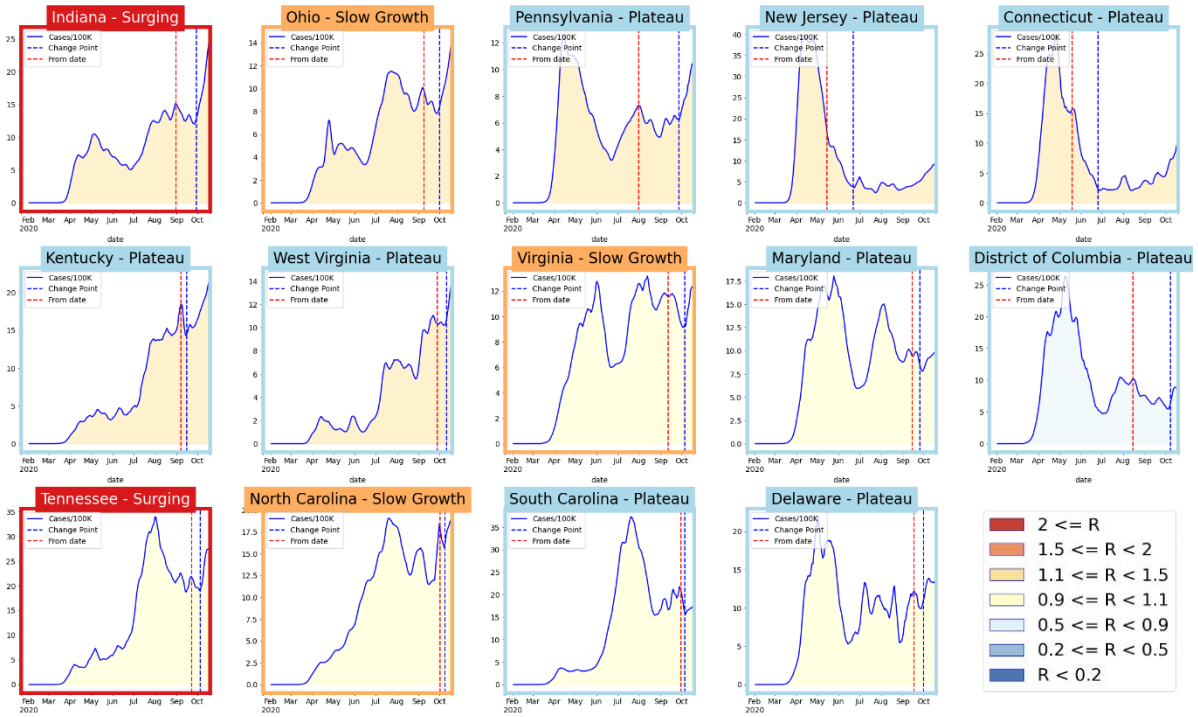
Shift back to higher income zip codes partially driven by surges in areas surrounding universities, which has since receded with the lower 40% bearing higher rates of disease



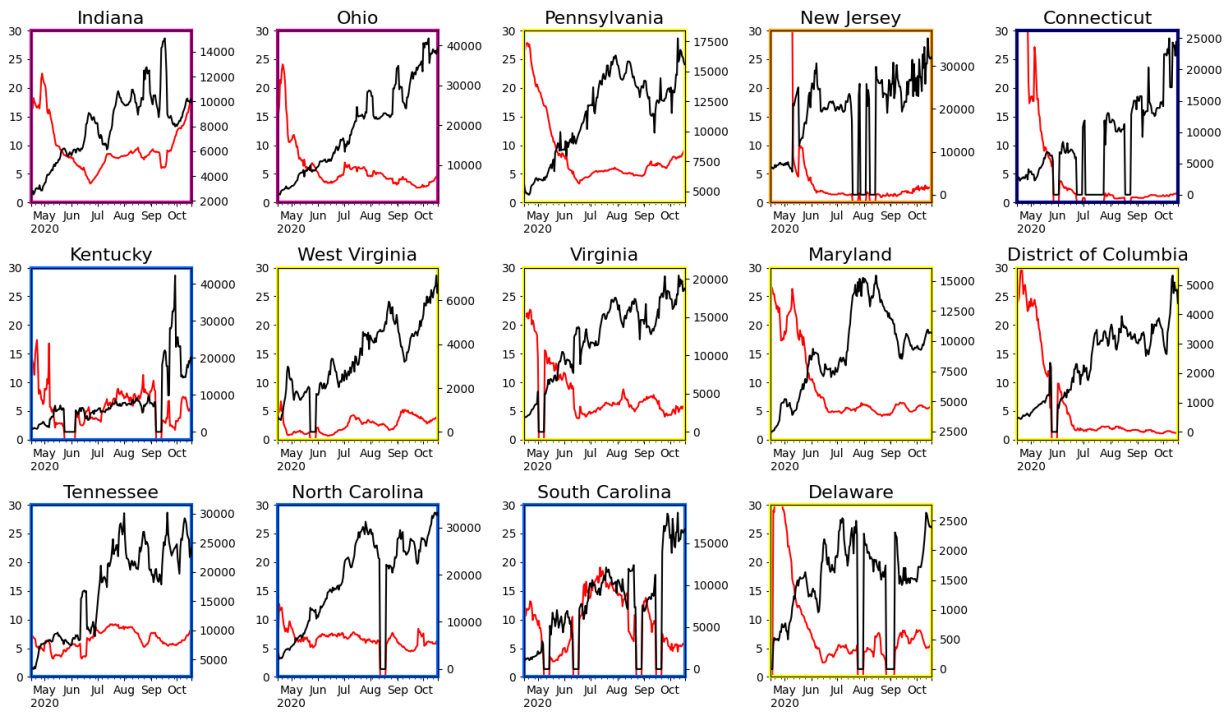
Can see the evolution from denser and wealthier zip codes to poorer and less dense zip codes, then back to denser wealthier zip codes, with an additional shift back again to poorer and less dense ares

Other State Comparisons

Trajectories of States



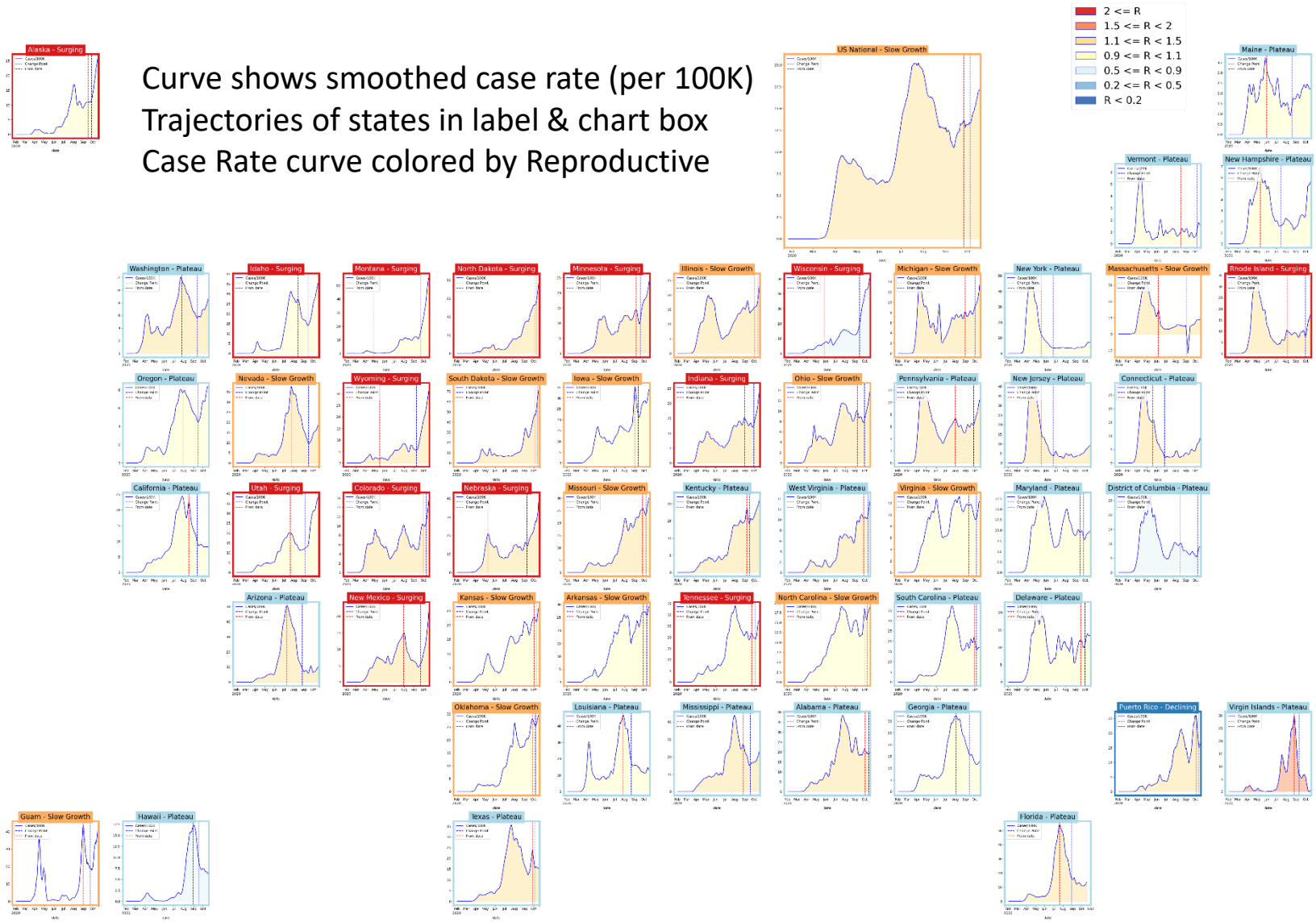
Tests per Day and Test Positivity



- VA just barely into slow growth territory along with NC
- TN and IN join 15 other states in surge across nation
- Most of the Mid-Atlantic experiencing Plateau headed upward

- Test positivity mixed, VA's declining rate has slowed.
- Testing volumes remain steady and relatively high

United States Trajectories & Case Rates (per 100K)



Curve shows smoothed case rate (per 100K)
Trajectories of states in label & chart box
Case Rate curve colored by Reproductive

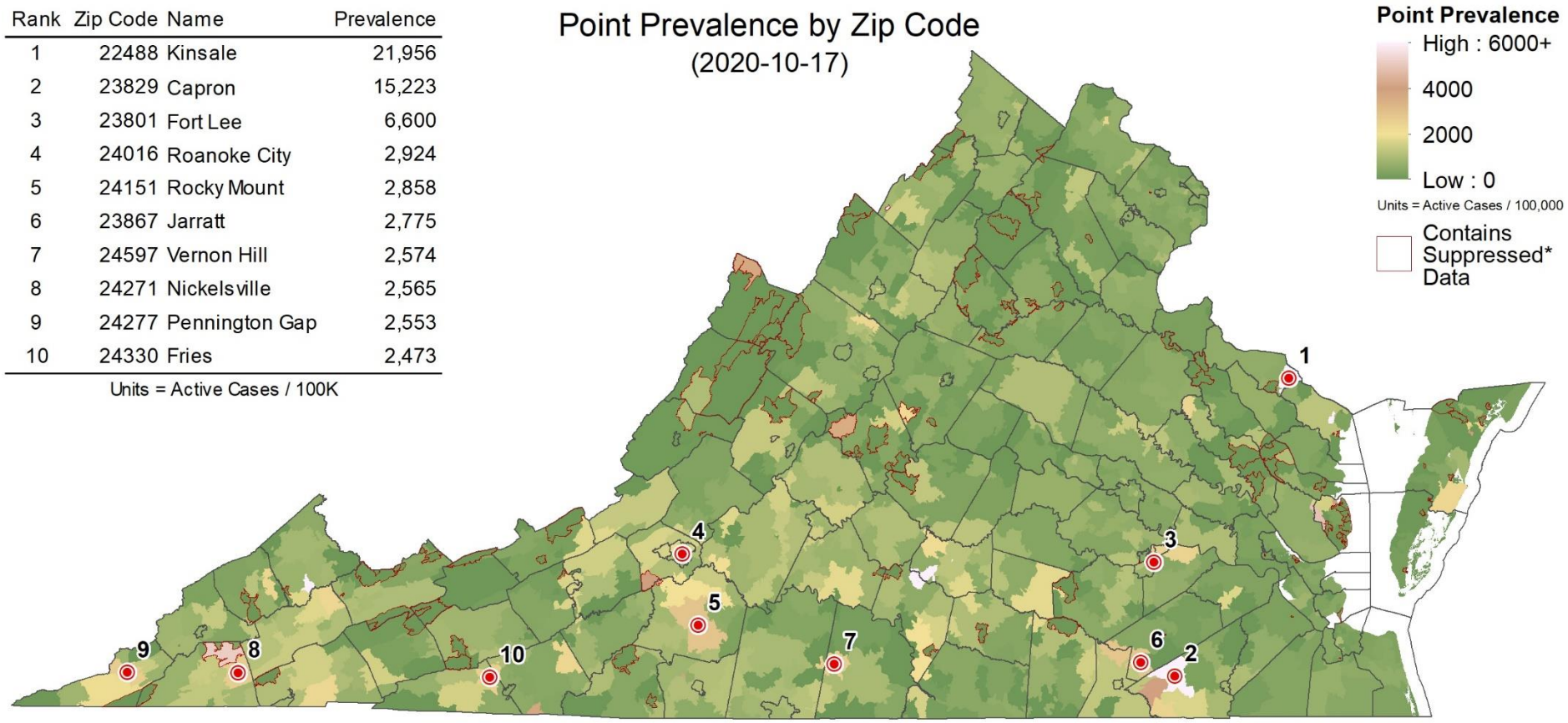
Zip code level weekly Case Rate (per 100K)

Case Rates in the last week by zip code

- Concentrations of very high prevalence in some zip codes
- High prevalence zips scattered across the commonwealth, mostly in the southern half
- Some counts are low and suppressed to protect anonymity, those are shown in white

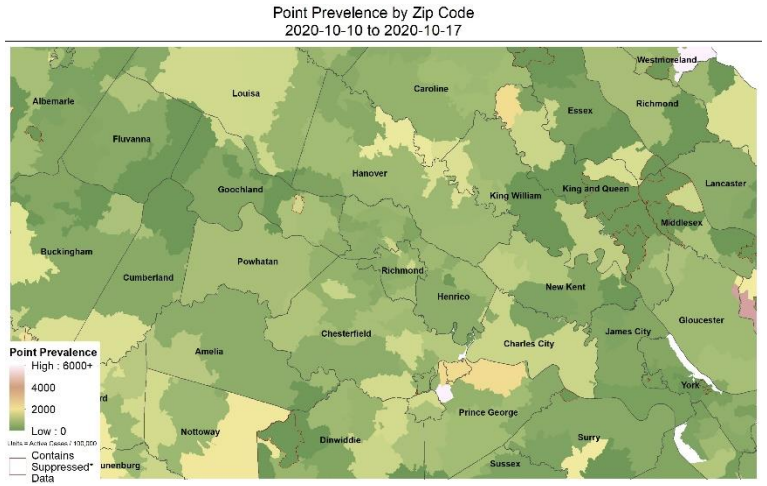
Rank	Zip Code	Name	Prevalence
1	22488	Kinsale	21,956
2	23829	Capron	15,223
3	23801	Fort Lee	6,600
4	24016	Roanoke City	2,924
5	24151	Rocky Mount	2,858
6	23867	Jarratt	2,775
7	24597	Vernon Hill	2,574
8	24271	Nickelsville	2,565
9	24277	Pennington Gap	2,553
10	24330	Fries	2,473

Units = Active Cases / 100K

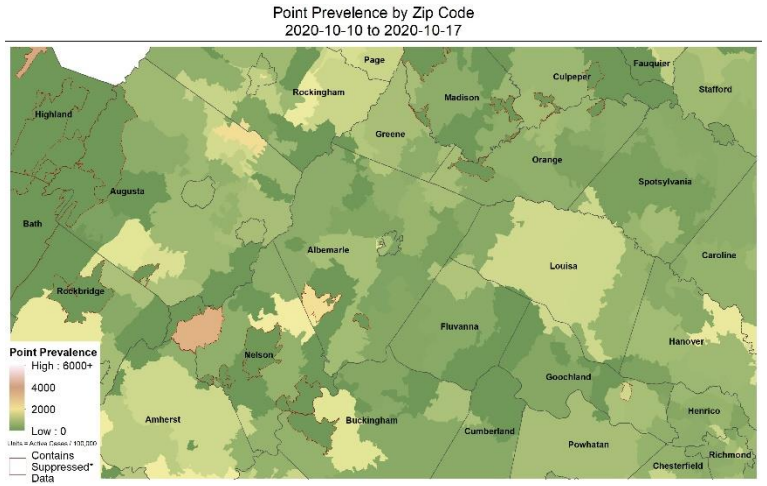


Zip code level weekly Case Rate (per 100K)

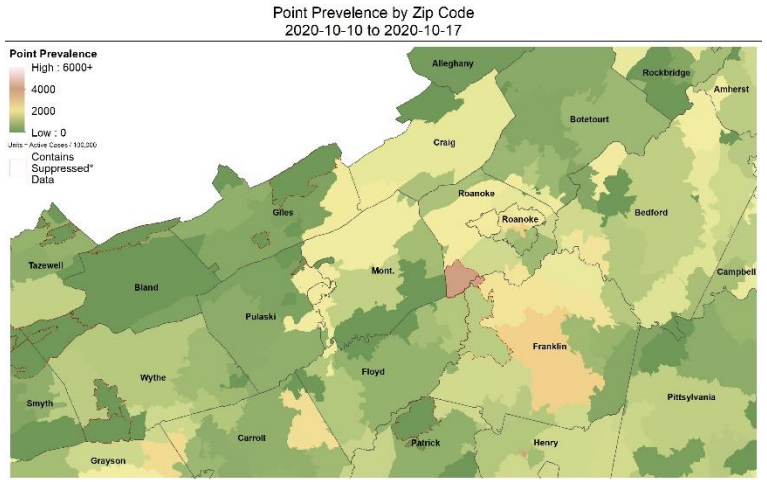
Richmond



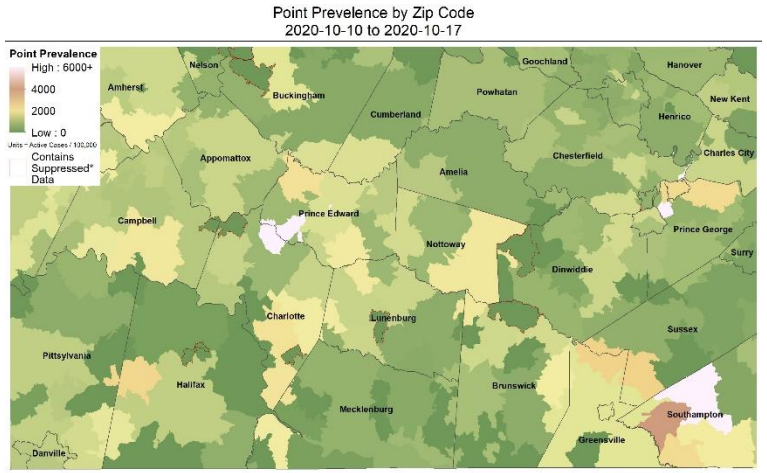
Albemarle



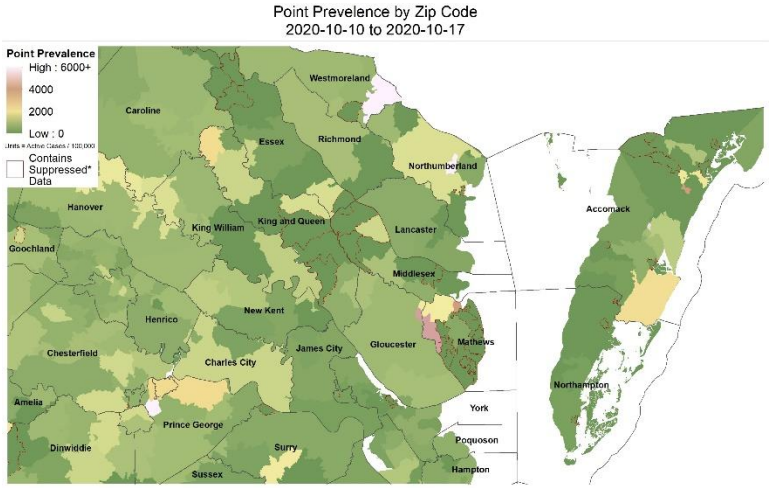
New River Valley



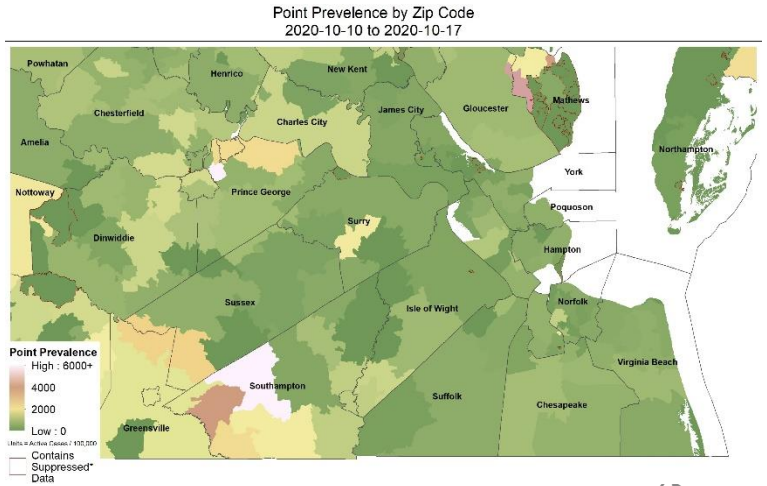
Southside



Three Rivers



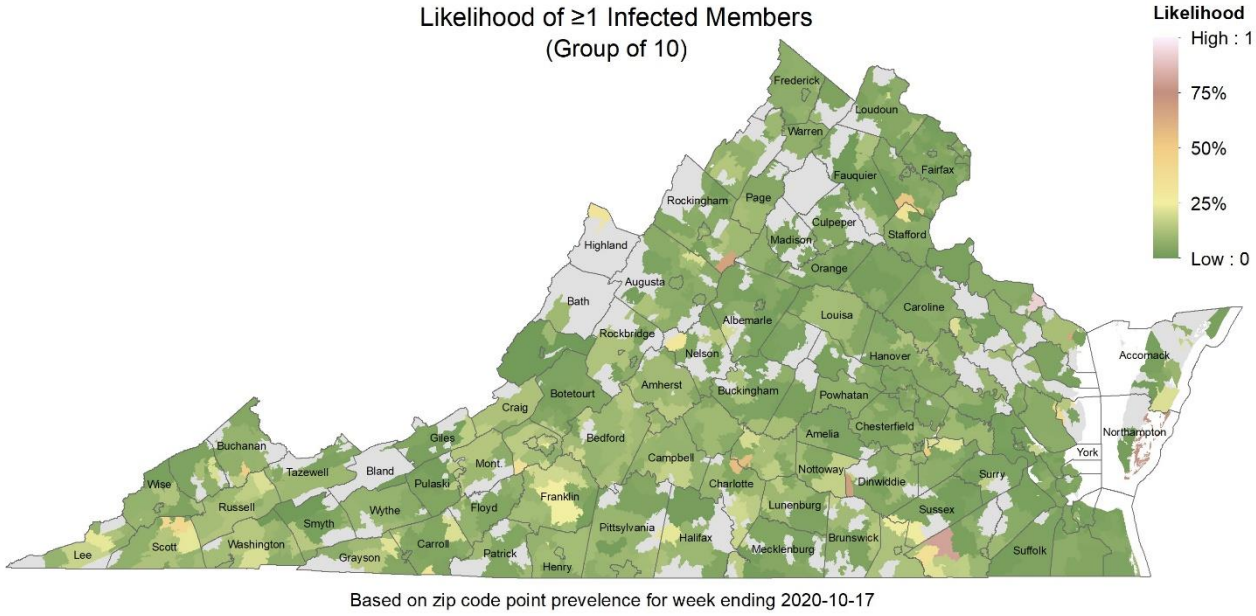
Tidewater

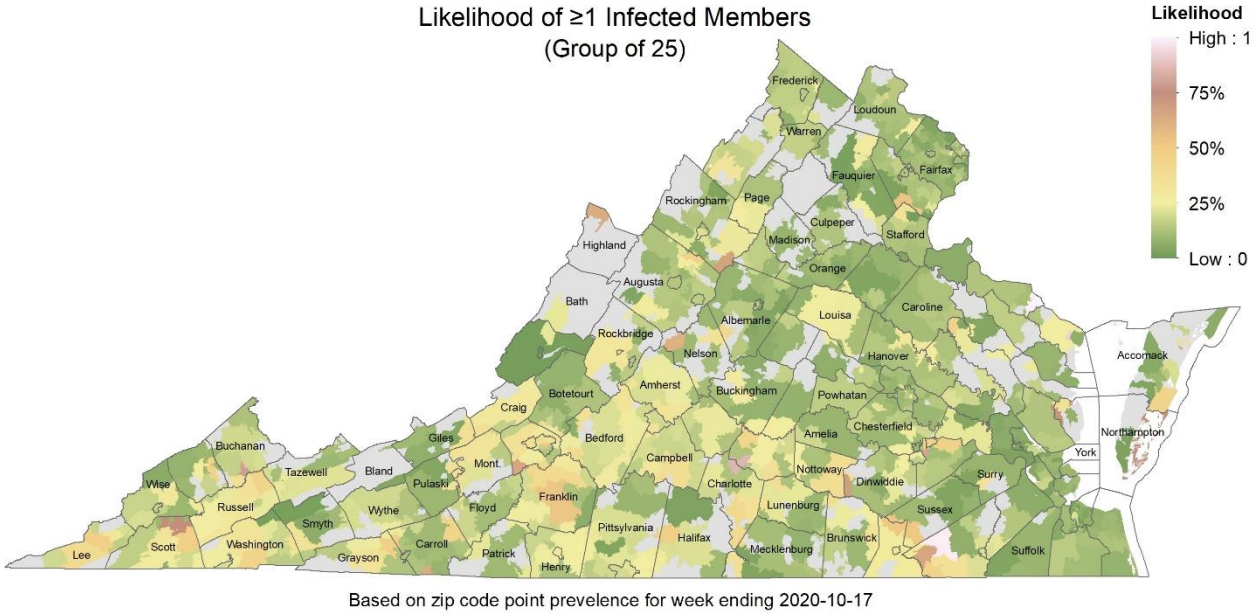


Risk of Exposure by Group Size

Case Prevalence in the last week by zip code used to calculate risk of encountering someone infected in a gathering of randomly selected people (group size 10 or 25)

- Moderate risk for groups of 25 across the commonwealth, especially in the southern half of the state
- Some zip codes have high likelihood of exposure even in groups of 10





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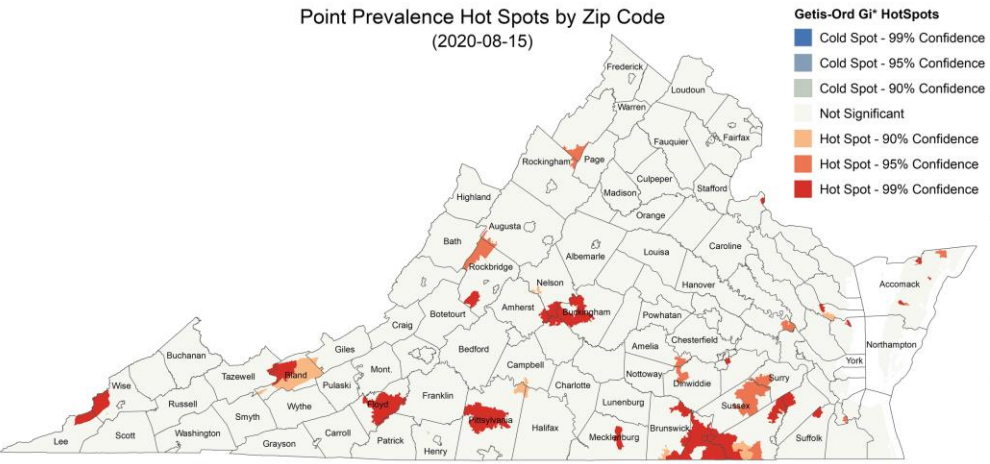
Zip Code Hot Spots

Previous weeks

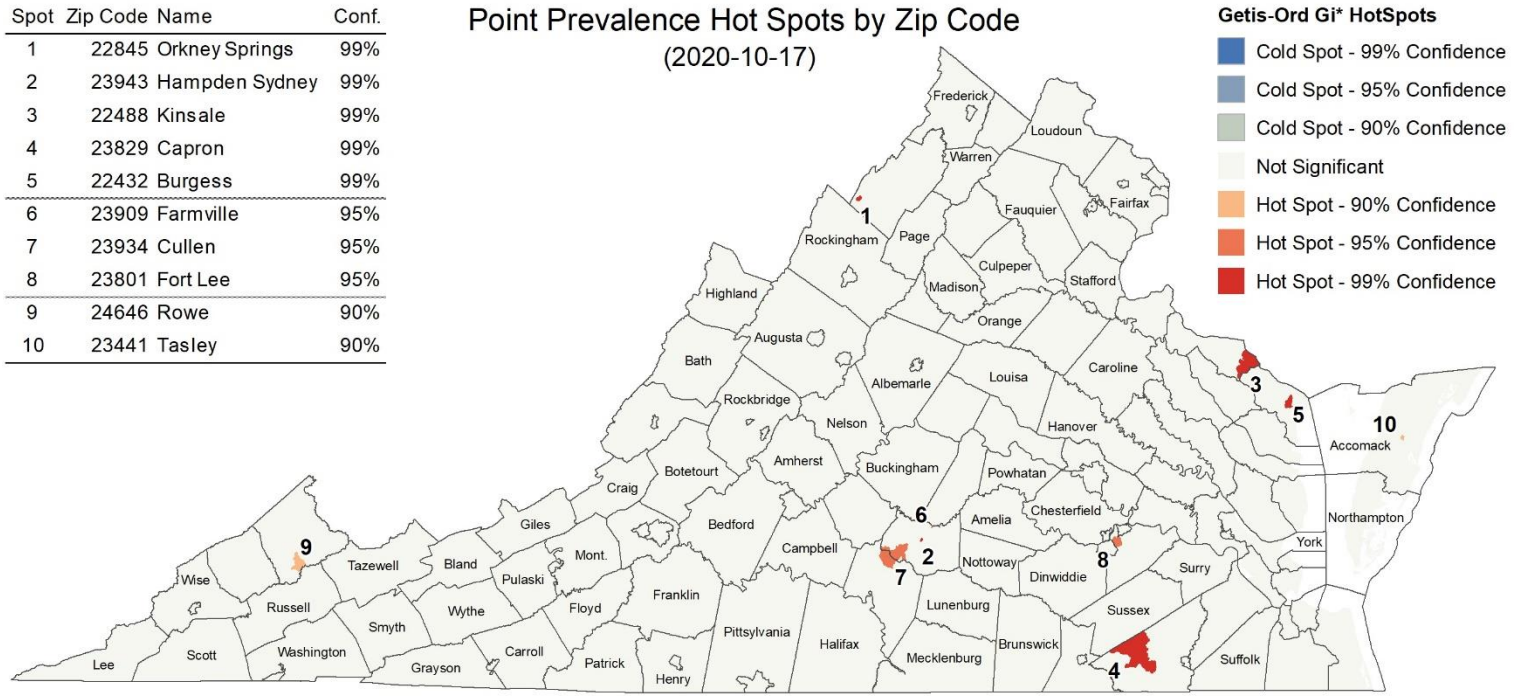


Hotspots across commonwealth

- Similar number of hotspots this week compared to last week
- Fewer university associated hotspots

Spot	Zip Code	Name	Conf.
1	22845	Orkney Springs	99%
2	23943	Hampden Sydney	99%
3	22488	Kinsale	99%
4	23829	Capron	99%
5	22432	Burgess	99%
6	23909	Farmville	95%
7	23934	Cullen	95%
8	23801	Fort Lee	95%
9	24646	Rowe	90%
10	23441	Tasley	90%

Hot Spot Significance	# of Zips (last week)
99%	5 (8)
95%	3 (1)
90%	2 (1)



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Model Update – Adaptive Fitting

Adaptive Fitting Approach

Each county fit precisely, with recent trends used for future projection

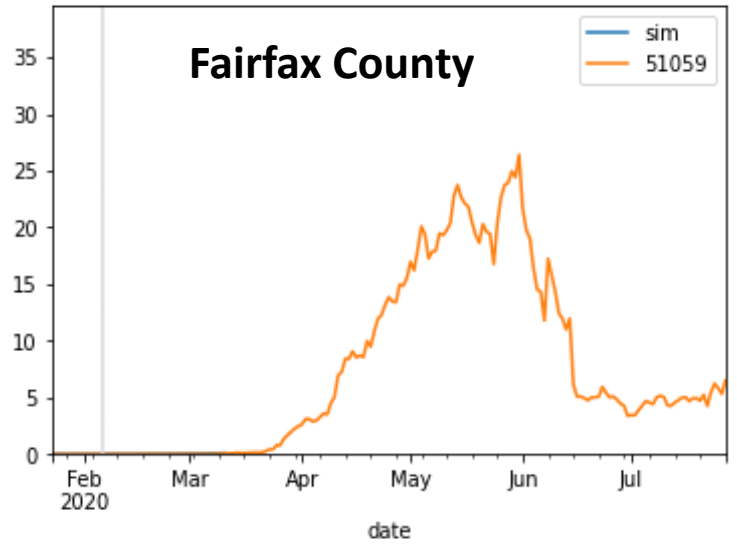
- Allows history to be precisely captured, and used to guide bounds on projections

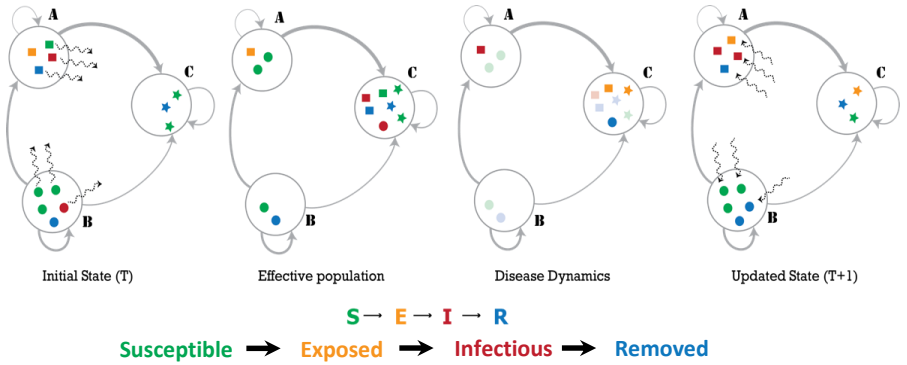
Model: An alternative use of the same meta-population model, PatchSim

- Allows for future "what-if" Scenarios to be layered on top of calibrated model
- Eliminates connectivity between patches, to allow calibration to capture the increasingly unsynchronized epidemic

External Seeding: Steady low-level importation

- Widespread pandemic eliminates sensitivity to initial conditions
- Uses steady 1 case per 10M population per day external seeding





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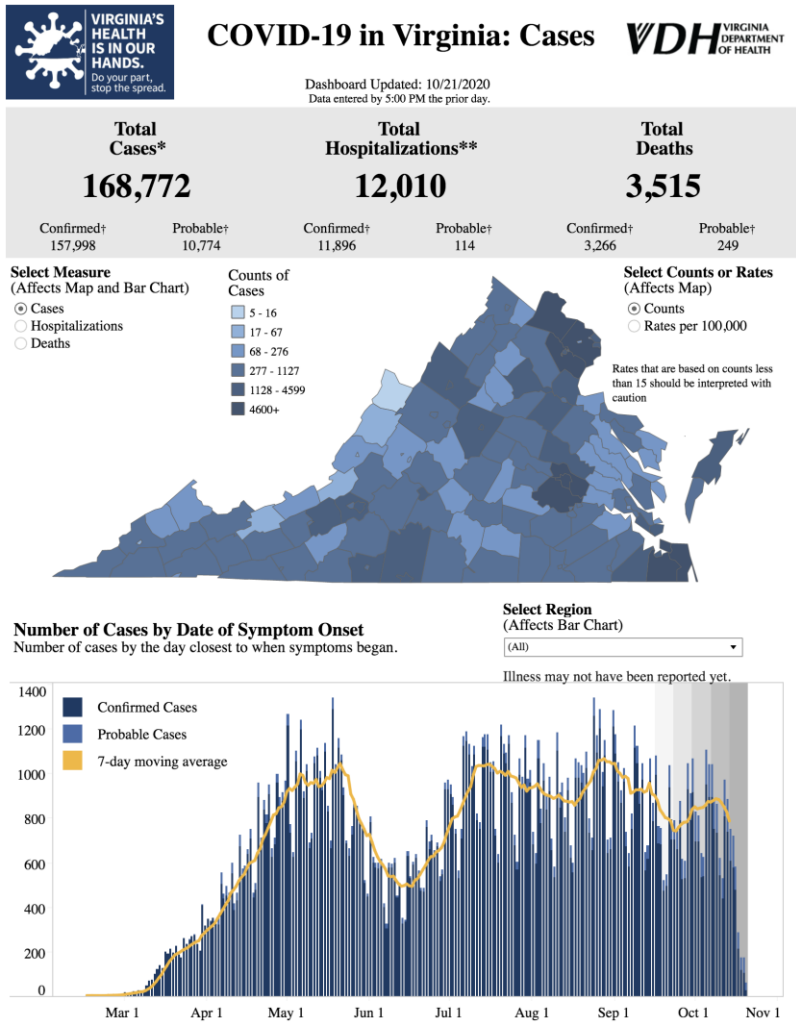
Calibration Approach

- **Data:**
  - County level case counts by date of onset (from VDH)
  - Confirmed cases for model fitting
- **Calibration:** fit model to observed data
  - Tune transmissibility across ranges of:
    - Duration of incubation (5-9 days), infectiousness (3-7 days)
    - Undocumented case rate (3x to 12x)
    - Detection delay: exposure to confirmation (4-12 days)
  - Approach captures uncertainty, but allows model to precisely track the full trajectory of the outbreak
- **Project:** future cases and outcomes using the most recent parameters with constraints learned from the history of the fit parameters
  - Mean trend from last 7 days used, adjusted by variances in the previous 3 weeks
  - 1 week interpolation to smooth transitions in rapidly changing trajectories
  - Particles with high error or variance filtered out



Accessed 9:30am October 21, 2020
https://www.vdh.virginia.gov/coronavirus/

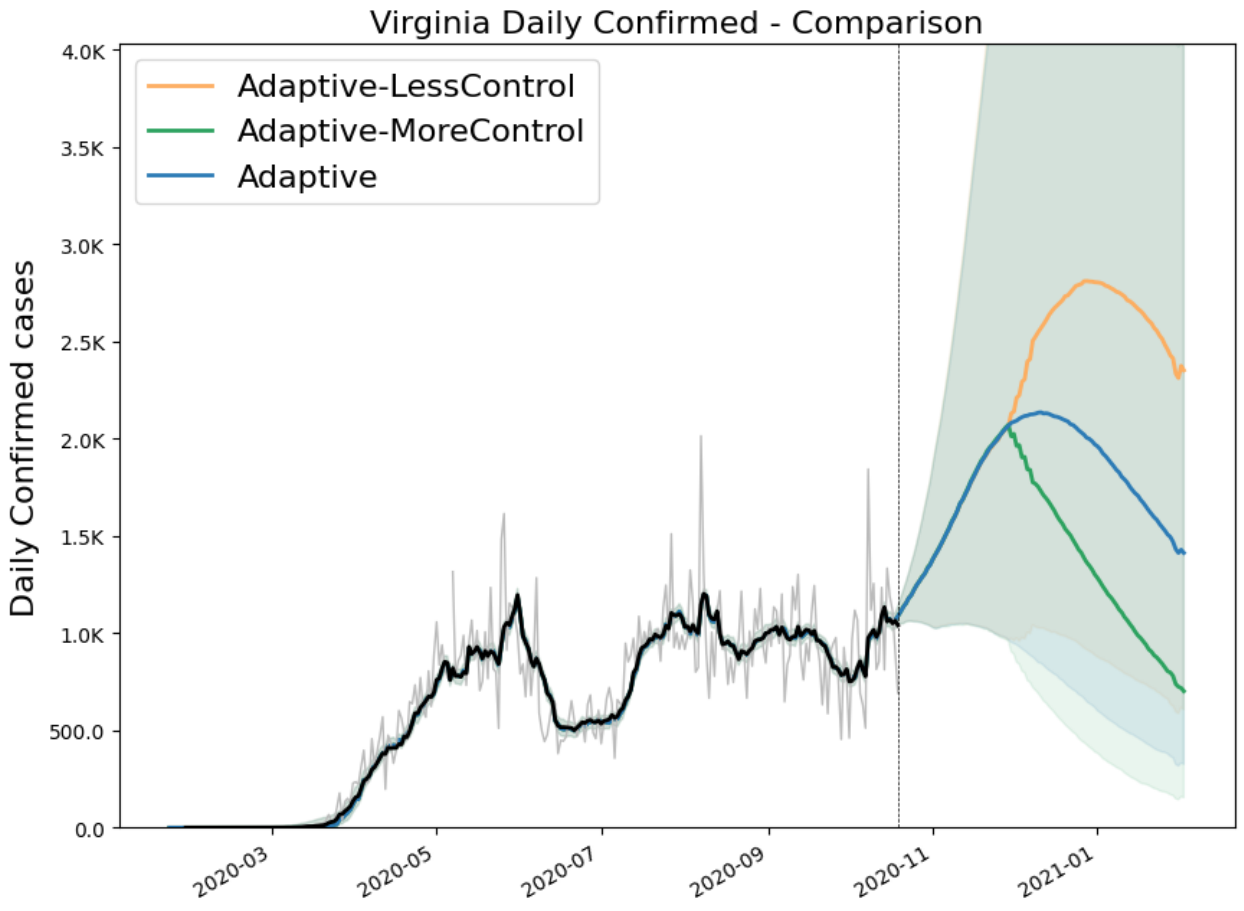
Scenarios – Seasonal Effects

- Societal changes in the past month have led to an increase in transmission rates, these could continue to drive transmission
  - Seasonal impact of weather patterns
  - More interactions at places of learning
  - Travel related to holidays and traditional large family gatherings
  - Fatigue with infection control practices
- Population's behaviors determine the level of control of transmission we can achieve
- Three scenarios capture possible trajectories starting Nov 26th, 2020
  - Adaptive: No change from base projection
  - Adaptive-MoreControl: 15% decrease in transmission starting Nov 26th, 2020
  - Adaptive-LessControl: 15% increase in transmission starting Nov 26th, 2020

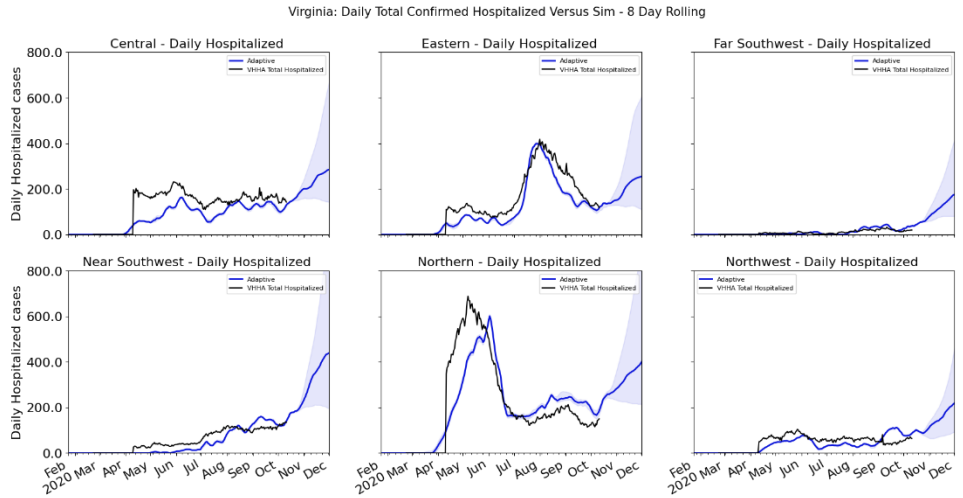
Model Results

Outcome Projections

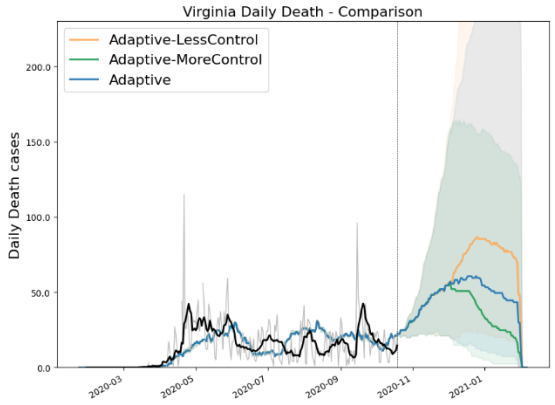
Confirmed cases



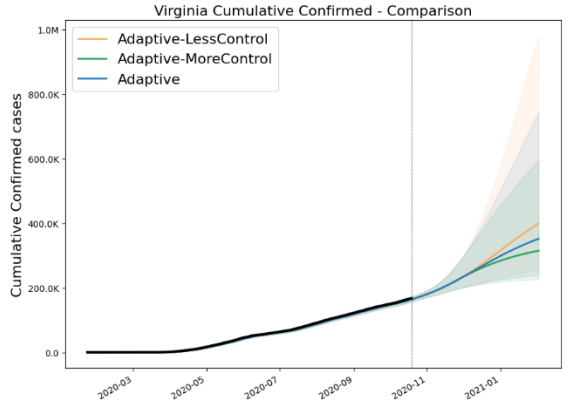
Estimated Hospital Occupancy



Daily Deaths



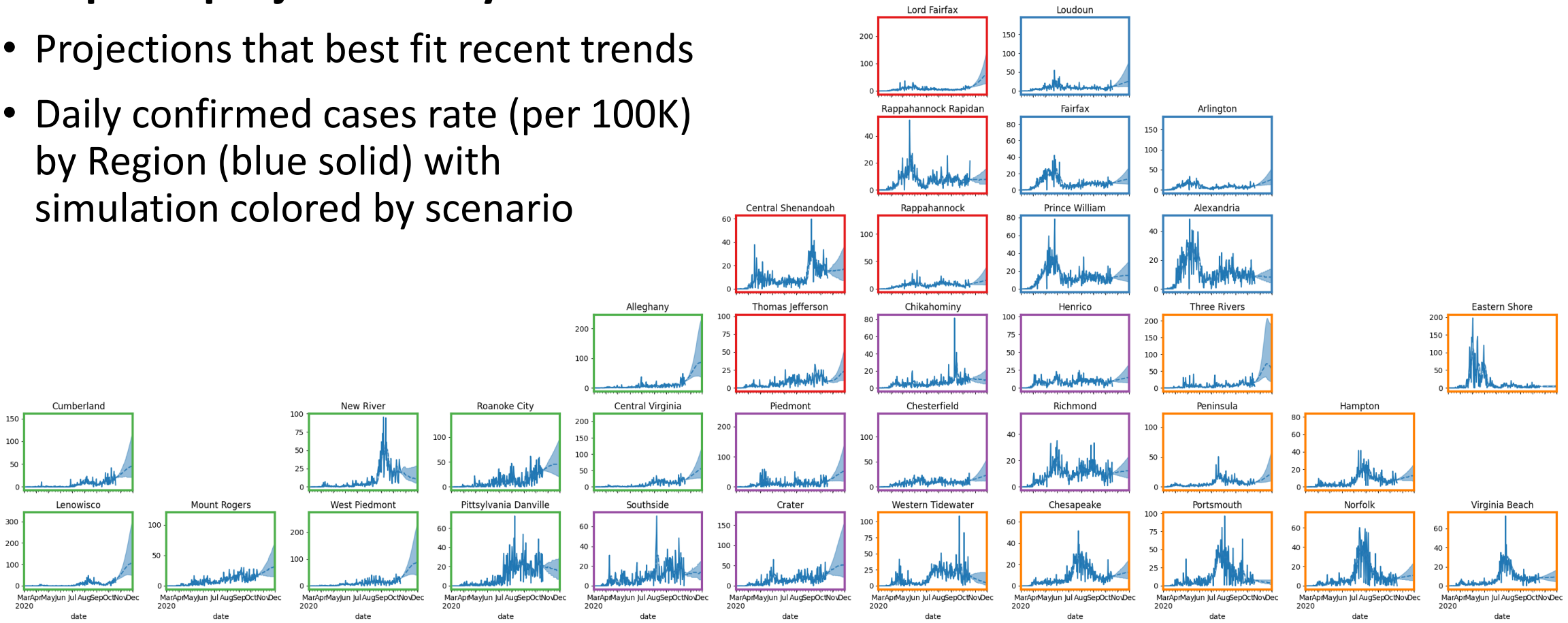
Cumulative Confirmed cases



District Level Projections: Adaptive

Adaptive projections by District

- Projections that best fit recent trends
- Daily confirmed cases rate (per 100K) by Region (blue solid) with simulation colored by scenario



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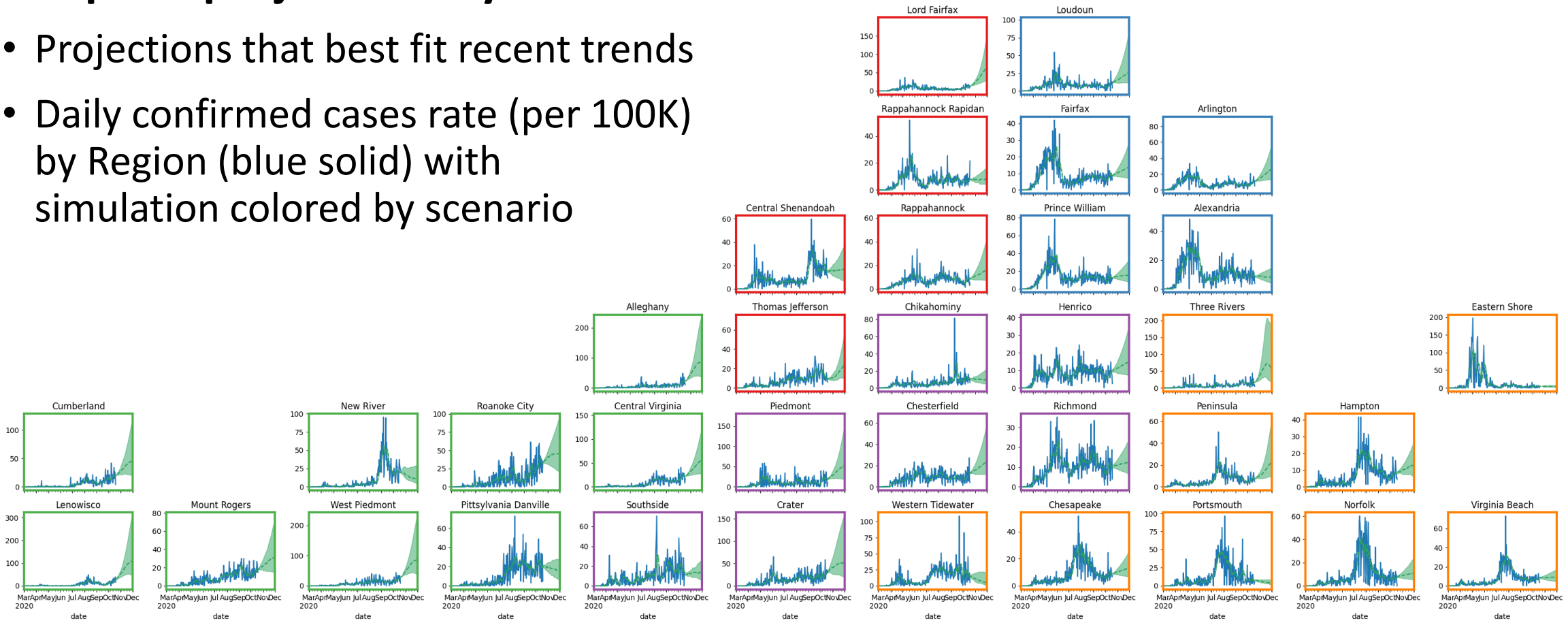
District Level Projections: Adaptive-MoreControl

Adaptive projections by District

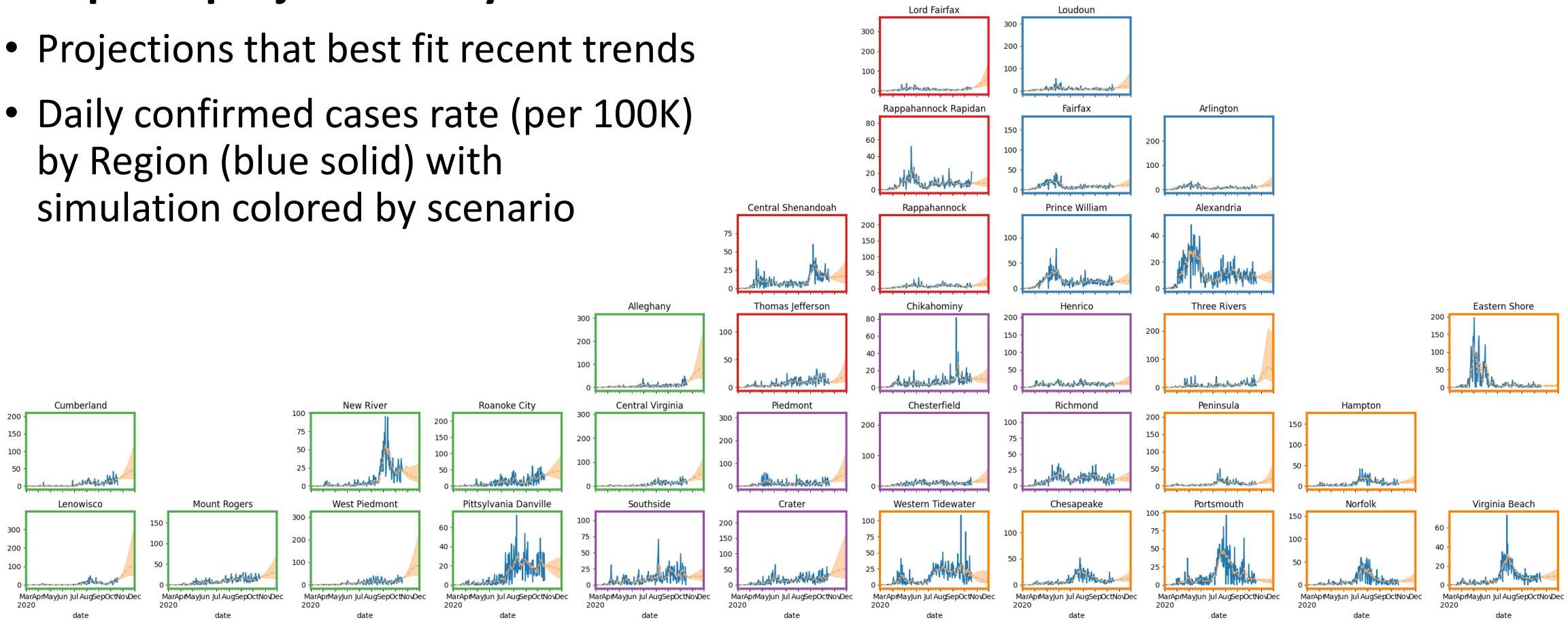
- Projections that best fit recent trends
- Daily confirmed cases rate (per 100K) by Region (blue solid) with simulation colored by scenario



District Level Projections: Adaptive-LessControl

Adaptive projections by District

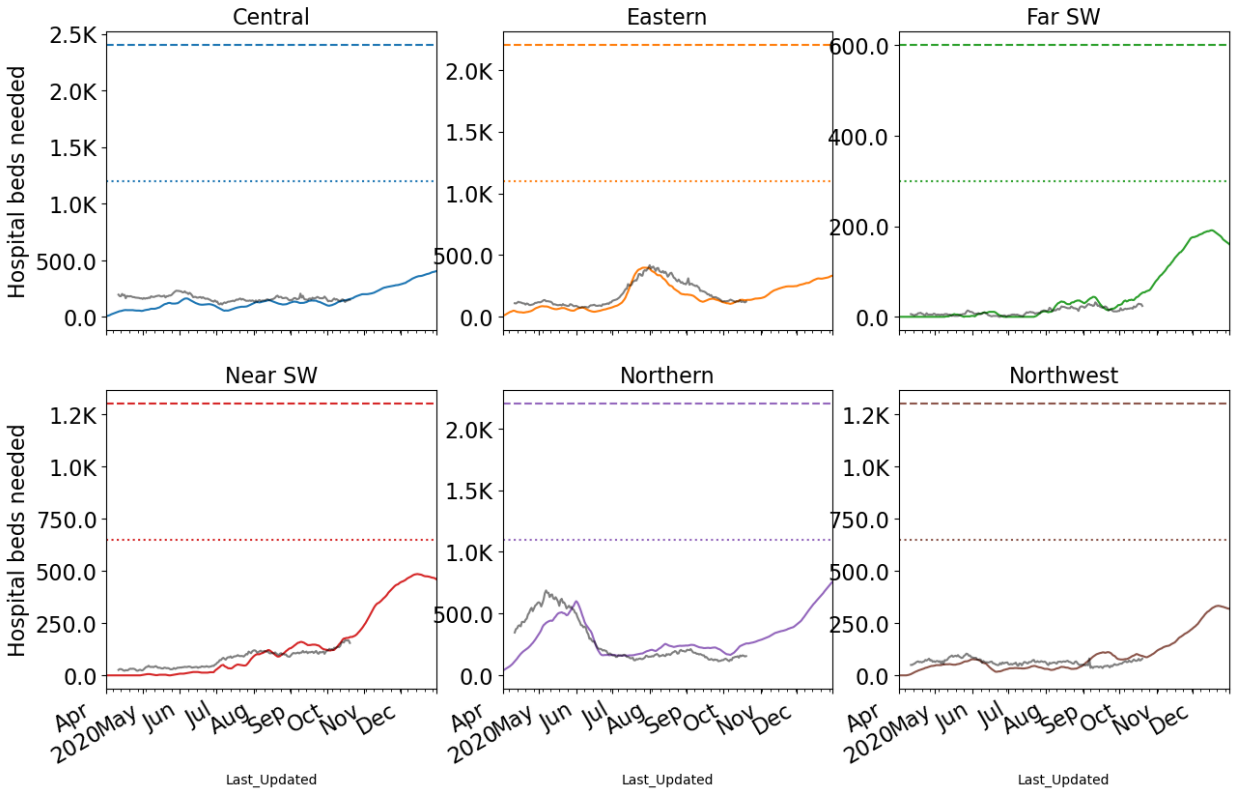
- Projections that best fit recent trends
- Daily confirmed cases rate (per 100K) by Region (blue solid) with simulation colored by scenario



Hospital Demand and Bed Capacity by Region

Capacities by Region – Adaptive-LessControl

COVID-19 capacity ranges from 80% (dots) to 120% (dash) of total beds



Week Ending	Adaptive	Adaptive-LessControl
10/11/20	7,468	7,468
10/18/20	8,085	8,087
10/25/20	9,179	9,183
11/1/20	10,398	10,395
11/8/20	11,809	11,795
11/15/20	13,150	13,135
11/22/20	14,122	14,099
11/29/20	14,712	15,700
12/06/20	14,911	17,755
12/13/20	14,781	18,791
12/20/20	14,389	19,443
12/27/20	13,793	19,636

Based on Adaptive-LessControl scenario: no regions forecast to exceed capacity

* Assumes average length of stay of 8 days

Key Takeaways

Projecting future cases precisely is impossible and unnecessary.
Even without perfect projections, we can confidently draw conclusions:

- **Virginia is steady while many states surge, though growth outpaces declines in the districts.**
- VA weekly incidence (11.6/100K) is steady and below the growing national average (23/100K).
- Projections are mostly up, but many districts continue to decline.
- Recent updates:
  - Planning Scenarios adjusted, as Adaptive Fitting tracks recent surge, to represent population's ability to exert further control on transmission following Thanksgiving holidays, Nov 26th.
  - Design used to capture uncertainty adjusted to better capture higher case ascertainment.
- The situation is changing rapidly. Models will be updated regularly.

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Google. COVID-19 community mobility reports. https://www.google.com/covid19/mobility/

Biocomplexity page for data and other resources related to COVID-19: https://covid19.biocomplexity.virginia.edu/

Questions?

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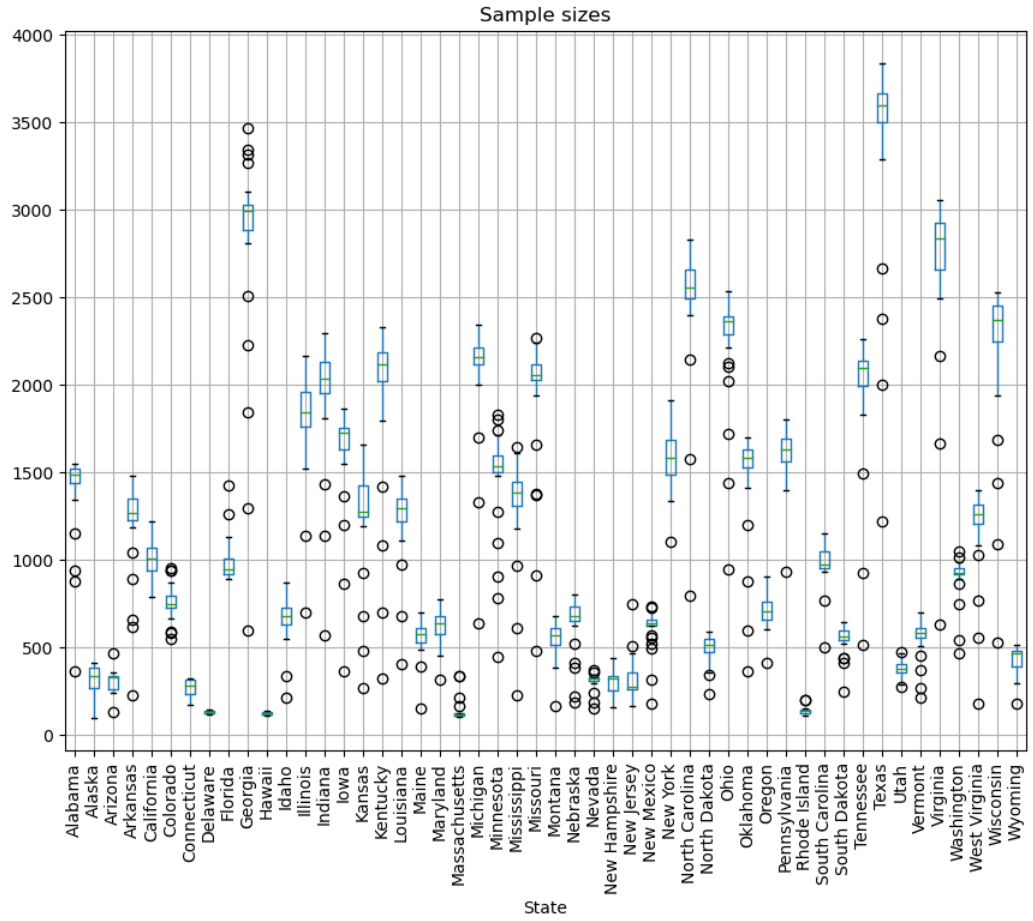
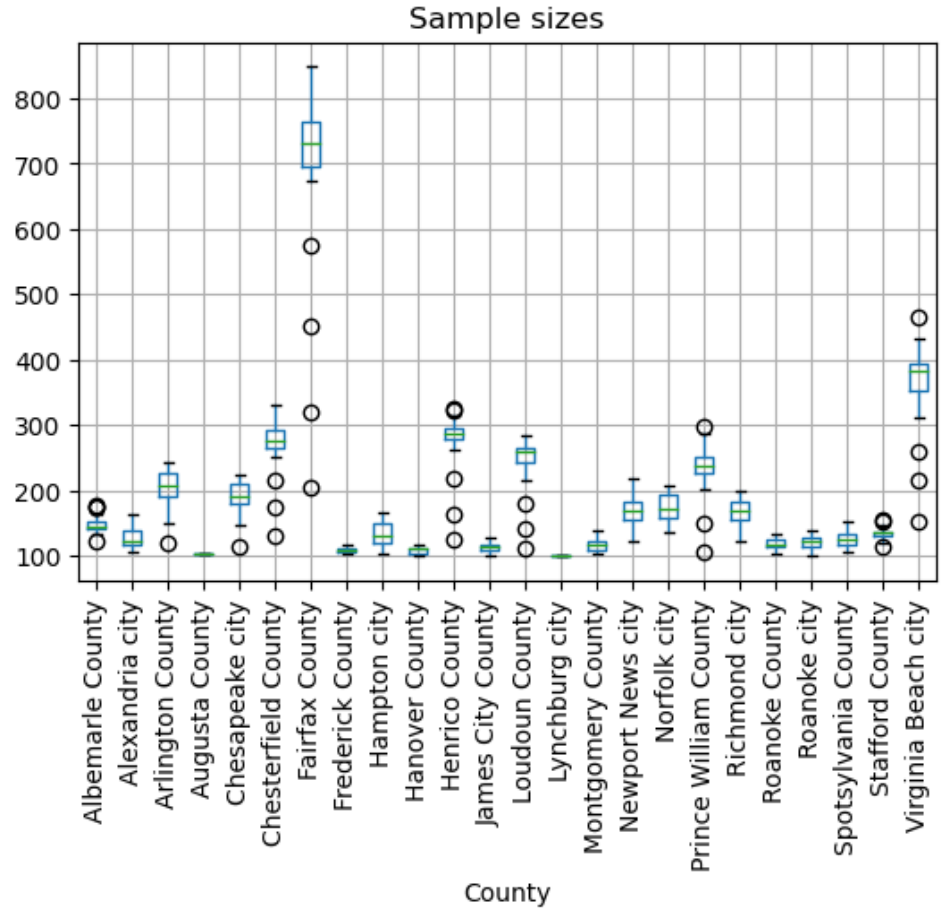
Supplemental Slides

Mask usage sample sizes





Test positivity across VA counties

- CMS weekly summary (used for guiding nursing homes testing protocol)
- Data: COVID-19 Electronic Lab Reporting (CELR); HHS Unified Testing Dataset;
- County level testing counts and test positivity rates for RT-PCR tests.
  - Green: Test positivity <5.0% or with <20 tests in past 14 days
  - Yellow: Test positivity 5.0%-10.0% or with <500 tests and <2000 tests/100k and >10% positivity over 14 days
  - Red: >10.0% and not meeting the criteria for "Green" or "Yellow"

https://data.cms.gov/stories/s/q5r5-gjyu

County	Sep-16	Sep-23	Sep-30	Oct-07
Amherst County	Yellow	Yellow	Yellow	Red
Bedford County	Yellow	Yellow	Yellow	Red
Campbell County	Yellow	Yellow	Yellow	Red
Charlotte County	Yellow	Green	Red	Red
Dinwiddie County	Yellow	Yellow	Yellow	Red
Franklin County	Yellow	Red	Red	Red
Greensville County	Red	Yellow	Red	Red
Manassas City	Yellow	Red	Yellow	Red
Martinsville City	Yellow	Yellow	Yellow	Red
Mathews County	Yellow	Yellow	Red	Red
Pittsylvania County	Red	Red	Red	Red
Prince George County	Yellow	Red	Red	Red
Rockingham County	Red	Red	Red	Red
Southampton County	Red	Red	Red	Red
Suffolk City	Red	Yellow	Yellow	Red
Surry County	Red	Red	Red	Red
Washington County	Red	Yellow	Red	Red
Wise County	Yellow	Yellow	Yellow	Red

Red on Oct-07

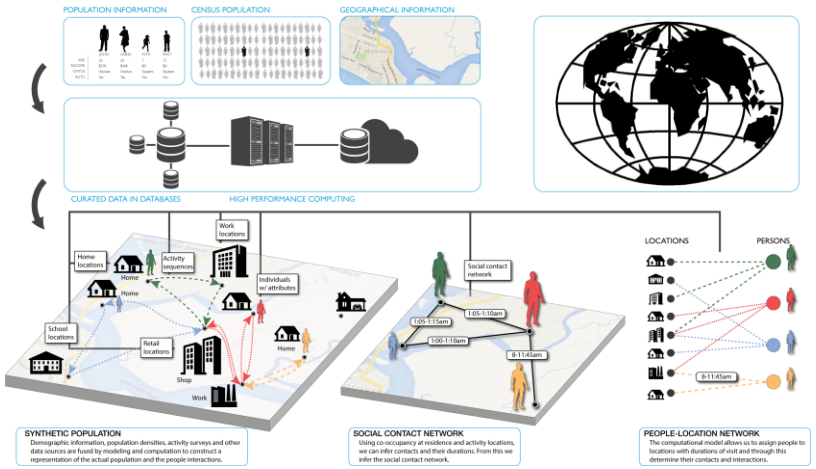
County	Sep-16	Sep-23	Sep-30	Oct-07
Augusta County	Red	Red	Yellow	Green
Bland County	Red	Yellow	Green	Green
Bristol City	Red	Yellow	Yellow	Yellow
Caroline County	Red	Yellow	Yellow	Yellow
Danville City	Red	Yellow	Yellow	Yellow
Fairfax County	Red	Yellow	Yellow	Yellow
Franklin City	Red	Red	Yellow	Yellow
Grayson County	Red	Red	Red	Yellow
Greensville County	Red	Yellow	Red	Red
Hanover County	Red	Yellow	Yellow	Yellow
Harrisonburg City	Red	Red	Red	Yellow
Henry County	Red	Red	Red	Yellow
Isle of Wight County	Red	Yellow	Yellow	Yellow
King and Queen County	Red	Yellow	Yellow	Green
Lancaster County	Red	Red	Yellow	Yellow
Loudoun County	Red	Yellow	Yellow	Yellow
Montgomery County	Red	Red	Yellow	Yellow
Northumberland County	Red	Red	Yellow	Yellow
Nottoway County	Red	Yellow	Yellow	Yellow
Pittsylvania County	Red	Red	Red	Red
Portsmouth City	Red	Red	Yellow	Yellow
Prince William County	Red	Yellow	Yellow	Yellow
Pulaski County	Red	Red	Yellow	Green
Radford City	Red	Yellow	Green	Green
Roanoke City	Red	Yellow	Yellow	Yellow
Roanoke County	Red	Red	Yellow	Yellow
Rockingham County	Red	Red	Red	Red
Salem City	Red	Red	Yellow	Yellow
Smyth County	Red	Yellow	Yellow	Yellow
Southampton County	Red	Red	Red	Red
Staunton City	Red	Yellow	Green	Green
Suffolk City	Red	Yellow	Yellow	Red
Surry County	Red	Red	Red	Red
Sussex County	Red	Red	Red	Yellow
Washington County	Red	Yellow	Red	Red

Red on Sep-16

Agent-based Model (ABM)

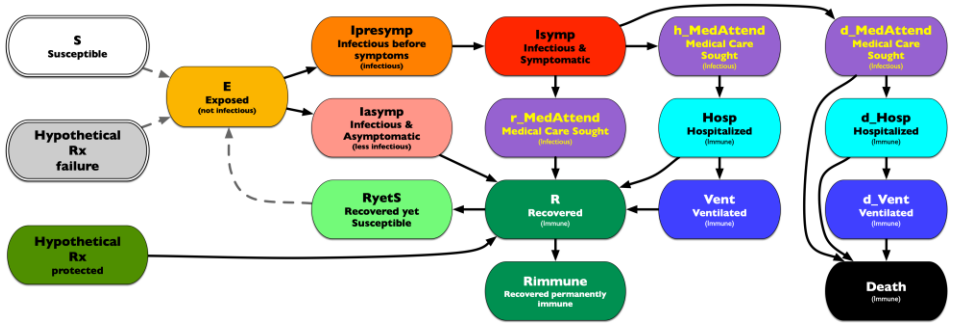
EpiHiper: Distributed network-based stochastic disease transmission simulations

- Assess the impact on transmission under different conditions
- Assess the impacts of contact tracing



Synthetic Population

- Census derived age and household structure
- Time-Use survey driven activities at appropriate locations



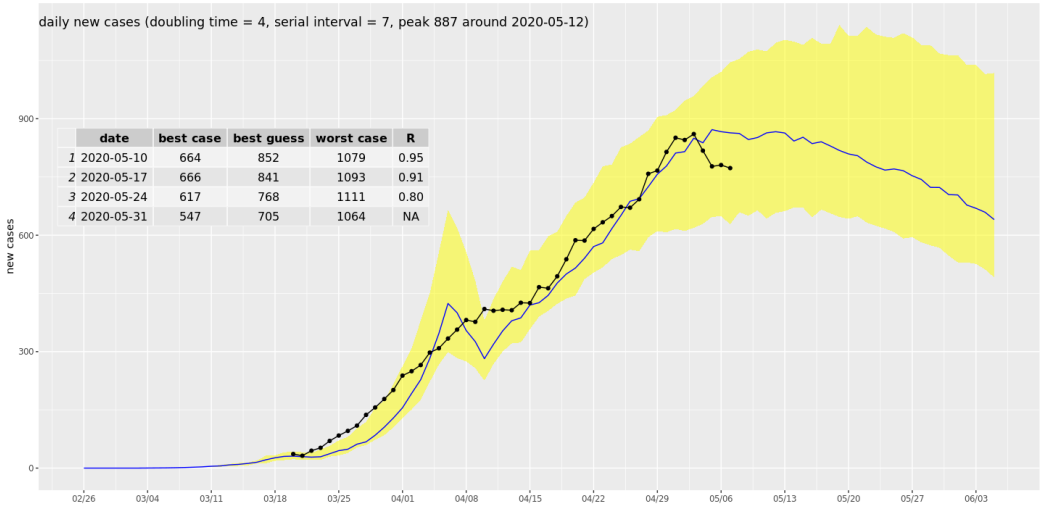
Detailed Disease Course of COVID-19

- Literature based probabilities of outcomes with appropriate delays
- Varying levels of infectiousness
- Hypothetical treatments for future developments

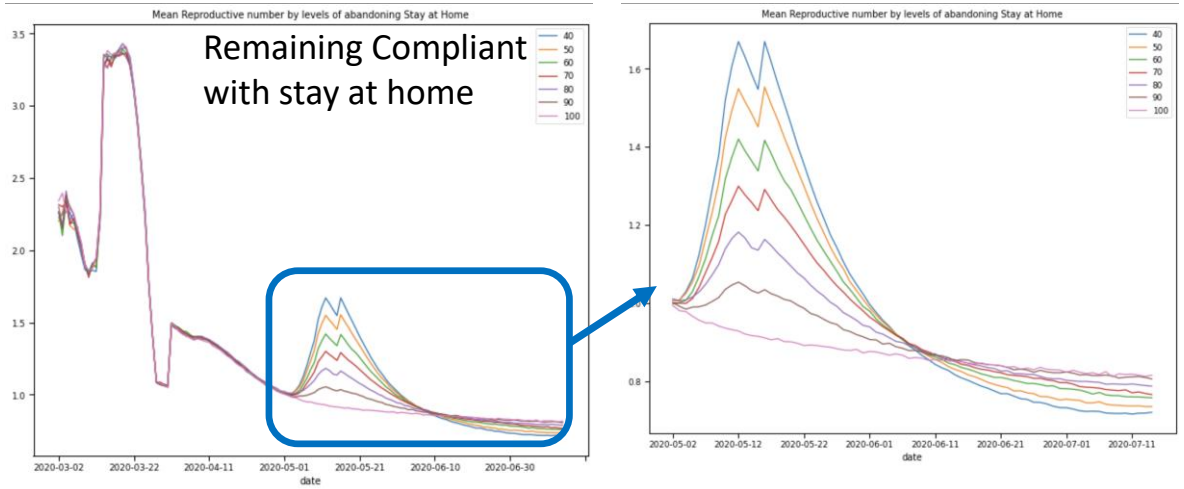
ABM Social Distancing Rebound Study Design

Study of ”Stay Home” policy adherence

- Calibration to current state in epidemic
- Implement “release” of different proportions of people from ”staying at home”



	date	best case	best guess	worst case	R
1	2020-05-10	664	852	1079	0.95
2	2020-05-17	666	841	1093	0.91
3	2020-05-24	617	768	1111	0.80
4	2020-05-31	547	705	1064	NA



Calibration to Current State

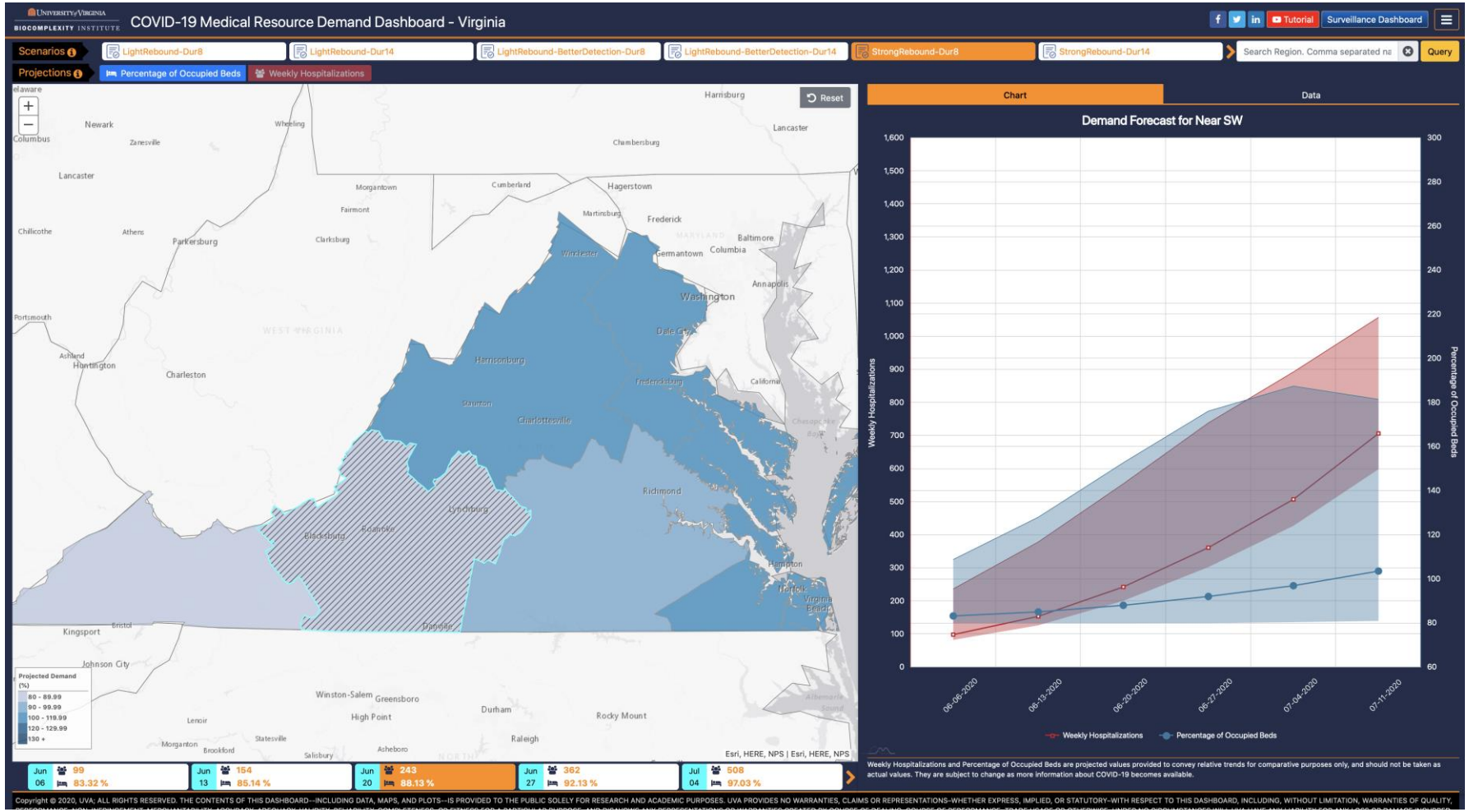
- Adjust transmission and adherence to current policies to current observations
- For Virginia, with same seeding approach as PatchSim

Impacts on Reproductive number with release

- After release, spike in transmission driven by additional interactions at work, retail, and other
- At 25% release (70-80% remain compliant)
- Translates to 15% increase in transmission, which represents a 1/6th return to pre-pandemic levels

Medical Resource Demand Dashboard

https://nssac.bii.virginia.edu/covid-19/vmrddash/



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